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PROLEGOMENA OF THE SPOTTED OWL (Strix occidentalis) IN SIX RIVERS NATIONAL FOREST

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Prolegomena of the Spotted Owl

(*Strix occidentalis*)

in Six Rivers National Forest

by

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ABSTRACT

Surveys were conducted of the northern spotted owl (Strix occidentalis caurina) in 24 timber sale study areas, totaling 82,627 ac (33,439 ha), in the Six Rivers National Forest in northwestern California. Sixty-eight spotted owls were discovered, representing 54 breeding pairs. A total of 315 calling stations, representing 5494 min (91.6 hr) of calling by voice or tape along 138.5 mi (222.8 km) of transects, yielded overall relative frequencies of 0.17 spotted owl territories per calling station, 0.98 per 100 min of calling, and 0.39 per mi (0.24 per km) transected.

Peaks in calling responsiveness were recorded as just a little after dusk, a little after midnight, and just before dawn.

Spotted owl territories were discovered in all vegetation types except oak woodland, which lacked sufficient cover and nest sites.

Overall crude density in all study areas was 1460 total ac (591 ha) per territory, or 0.65 territories per 1000 total ac (400 ha). Overall ecological density was 585 mature and old growth ac (237 ha) per territory, or 1.71 territories per 1000 mature and old growth ac (400 ha). These data indicate slightly higher spotted owl densities in northwestern California than other investigators have reported, inferring a major population center of northern spotted owls on the Six Rivers National Forest.

The field surveys indicated an association of spotted owl territories with mature or old growth douglas fir (Pseudotsuga menzeisii) stands, southern and western exposures (correlation may be spurious), and moderately steep slopes. Distances of 48 territories to the nearest known permanent water averaged 0.27 mi (0.44 km) and ranged 0-1.00 mi (0-1.61 km). Distances of 26 territories to the next nearest known territory averaged 1.09 mi (1.75 km) and ranged 0.27-2.82 mi (0.43-4.54 km), and 61 percent of the minimum distances between pairs were from 0.62 to 1.24 mi (1.00 to 2.00 km). Territories were more closely spaced along streamside habitat.

Data are discussed suggesting that spotted owls may forage along edge or in seral habitat, and that predation by great horned owls (Bubo virginianus) may limit the use of or proximity to seral habitat by spotted owls.

Minimum critical habitat sufficient for a breeding pair of

spotted owls seemed to be 200-300 ac (81-121 ha) of mature and old growth douglas fir.

Legal and ecological status of the spotted owl is discussed, and recommendations are made for the use of nest boxes and for future studies.

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INTRODUCTION

The distributional status of the northern spotted owl (*Strix occidentalis caurina*) in northwestern California is poorly known. Gould (1974) surveyed the north coastal region and recorded 41 pairs in Trinity, Humboldt, Del Norte, and Siskiyou Counties, six pairs of which were found on the Six Rivers National Forest. The most recent updates to Gould's surveys (Gould 1977, U.S. Forest Service 1978) adds 35 pairs to the four-county list, and other records (Six Rivers National Forest files) of unverified sightings add 14 more, for a total of 90. Gould (1977) reported a total of 191 northern spotted owls, representing 122 pairs, state-wide.

General accounts of the life history of the spotted owl have been given by Zarn (1974), Forsman (1976), Bent (1961), U.S. Forest Service (1975), McLean (1928), and others. Additional, limited surveys or reports of spotted owls in the north coast area have been given by Hill (1976), Williams (1977), and Erickson (no date). However, none of these reviews or reports supply sufficient information critical to the successful management of spotted owls on Forest Service land.

This study was prompted by the need for more intensive and local surveys on the Six Rivers National Forest (Six Rivers NF) in northwestern California. The goals of this research were to: 1) survey 24 potential timber sale areas for presence of breeding territories, 2) assess the ecological distribution of spotted owls in these areas, and 3) develop preliminary guidelines for management and future research of spotted owls on the Six Rivers NF.

This study was funded by the U.S. Forest Service under contract Order No. 43-9A47-8-392. I wish to thank Jack Kahl for shepherding the contract; Ronald Escano for his field assisstance and his invaluable comments and insights; Gordon Gould for supplying the work-series cassette tapes; Kurt Nelson for his analyses of guard hairs from the owl pellets; William Clow, John Brack, Robert Behrstock, and above all, Jeff Gardetto and Carter Cox for their extensive assistance in conducting the field surveys. The Six Rivers NF supplied maps and aerial photos of each study area.

THE STUDY AREAS

A total of 24 timber sale study areas were surveyed, spanning all four Ranger Districts of the Six Rivers NF (Table 1). The study areas totaled 82,627 ac (33,439 ha), and ranged from 807 to 14,366 ac (327 to 5816 ha) (see Table 4).

The study areas occurred in four major California vegetation types (Kuchler 1977) (Table 1). 1) Nine study areas occurred in Klamath Montane Forest With Douglas Fir. This vegetation type is dominated by douglas fir (Pseudotsuga menzeisii) and white fir (Abies concolor), with Shasta red fir (Abies magnifica var. shastensis) and mountain hemlock (Tsuga mertensiana) at higher elevations. Shrubs include manzanita (Arctostaphylos patula), tobacco brush (Ceanothus velutinus), and bitter cherry (Prunus emarginata). The general physiognomy of this type is a tall, dense to moderately open, needle-leaved evergreen forest with patches of broad-leaved evergreen shrubs and meadows.

2) One study area was in Coast Range Montane Forest, which is dominated by white fir, yellow pine (Pinus ponderosa), and douglas fir. Subdominants include manzanita (Arctostaphylos spp.), sugar pine (Pinus lambertiana), and California black oak (Quercus kelloggii). This is a tall, dense to moderately open, needle-leaved evergreen forest with scattered patches of broad-leaved evergreen shrubs.

3) Two study areas were in Oregon Oak Forest, dominated by Oregon white oak (Quercus garryana), with manzanita (Arctostaphylos patula), madrone (Arbutus menzeisii), yellow pine, bitter cherry, douglas fir, California black oak, and digger pine (Pinus sabiniana). This type is characterized as a medium tall, open to dense, broad-leaved deciduous forest with a mix of taller needle-leaved evergreen trees. Under open canopies, broad-leaved evergreen and some deciduous shrubs grow in varying density. A grassy ground cover may be continuous.

4) Eleven study areas were in Mixed Evergreen Forest with Chinquapin, dominated by madrone, tan oak (Lithocarpus densiflora), douglas fir, canyon live oak (Quercus chrysolepus), and chinquapin (Chrysolepis chrysophylla). Other trees may include sugar pine, yellow pine, California black oak, and Pacific yew (Taxus brevifolia). This type characteristically has an open canopy of tall needle-leaved evergreen trees, with a dense, broad-leaved evergreen understory with numerous shrubs.

Most study areas have had a history of past logging. Thus,

Table 1. The 24 timber sale (TS) study areas, by county, general legal location, Six Rivers National Forest Ranger District, vegetation type, and dates of survey. The study areas are listed roughly as they occurred north to south.

TS name	County	Legal location[a]	SRNF district	Veg. type[b]	Dates surveyed
Winchuck	Del Norte	T18N,R1E,Sec3,4,9 T19N,R1E,Sec33,34	Gasquet	21	12 April
Baker Flat	Del Norte	T18N,R3E,Sec11,12,13, 14,23,24	Gasquet	12	11 April
Jaws	Del Norte	T17N,R3E,Sec10,13,14, 15,21,22,23,24,25, 26,27,28,33,34,35, 36 T17N,R4E,Sec20,28,29, 32,33 T16N,R3E,Sec2,3	Gasquet	12/21	8-10 April
Butte Copter	Del Norte	T16N,R3E,Sec 1,12 T16N,R4E,Sec4,5,8,9,17	Gasquet	12	18 May
Camp Seven	Del Norte	T16N,R2E,Sec13,24,25, 26	Gasquet	21	24-25 March
Sugarloaf	Del Norte	T15N,R3E,Sec1,12,13, 14,23,26 T15N,R4E,Sec6,7	Gasquet	12	18 May
Pen Vista	Del Norte	T13N,R3E,Sec25,26,34, 35,36 T13N,R4E,Sec19,28,29, 30,31,32,33	Orleans	12	2 June

(Cont.)

Table 1. (Continued)

TS name	County	Legal location[a]	SRNF district	Veg. type[b]	Dates surveyed
Line	Siskiyou/ Humboldt	T12N,R5E,Sec25,26,34, 35,36 T11N,R5E,Sec1,2,3	Orleans	12	30 March
Wilson	Humboldt	T11N,R6E,Sec8,9,17, 18,19	Orleans	12	28-29 March
Dragon	Humboldt	T11N,R4E,Sec21,27,34 T10N,R4E,Sec2,3	Orleans	21	22-24 March
Creek	Humboldt	T11N,R4E,Sec26,35 T10N,R4E,Sec1,2	Orleans	21	22-24 March
Cape Horn	Humboldt	T11N,R5E,Sec33,34,35 T10N,R5E,Sec2,3,4	Orleans	21	5 April
Butte	Humboldt	T7N,R4E,Sec1,11,12,13, 14,15,16,17,20,21,22, 23,27,29,34,35 T6N,R4E,Sec3,4,5,6,7,8, 9,10,16,17,18	Lower Trinity	21	1,12 April
Maple	Humboldt	T7N,R5E,Sec14,23,24, 25	Lower Trinity	21	1 June
China	Humboldt	T6N,R4E,Sec1,11,12, 13,14 T6N,R5E,Sec4,5,9,16, 17,18,19	Lower Trinity	21	15-16 June
Willow	Humboldt	T6N,R4E,Sec15,21,22	Lower Trinity	21	17 June
East	Humboldt	T6N,R4E,Sec26,27,28, 33,34 T5N,R4E,Sec1,2,3,11	Lower Trinity	21	16 June

(Cont.)

Table 1. (Continued)

TS name	County	Legal location[a]	SRNF district	Veg. type[b]	Dates surveyed
Spike	Humboldt	T4N,R4E,Sec31,32,33 T4N,R5E,Sec5,6,7,8,18	Lower Trinity	12	13 June
Pilot Ridge	Humboldt	T4N,R4E,Sec26,35,36 T3N,R4E,Sec1,2,12 T3N,R5E,Sec7	Lower Trinity	12	30 June
Hastings/ Skull	Humboldt/ Trinity	T2N,R6E,Sec31,32,33 T1N,R6E,Sec4,5,8,9	Mad River	12	17 May
Brown	Humboldt/ Trinity	T2S,R5E,Sec22,23,24, 25,26,27,34,35,36	Mad River	14	25 May
Hetten	Trinity	T2S,R7E,Sec9,10,11, 14,15,16	Mad River	20	26 May
Shaw	Trinity	T2S,R7E,Sec20,21,22, 27,28,29,32,33	Mad River	20	26 May

[a]Humboldt Base Line Meridian.

[b]Kuchler's (1977) vegetation types:
12 - Klamath montane forest with douglas fir
14 - Coast Range montane forest
20 - Oregon oak forest
21 - Mixed evergreen forest with chinquapin
See text for descriptions.

the old growth areas - usually dominated by douglas fir with subdominants of white fir, yellow pine, or scattered hardwoods,- were interspersed by clear-cut areas containing only shrubs or shrubs intermixed with seedlings or saplings. Often the old growth occurred as islands roughly 10-100 ac (4-40 ha) in size.

METHODS

Field Surveys

Field surveys for spotted owls were conducted in 30 nights by soliciting vocal responses, from 22 March to 30 June 1978 (Fig. 1). During this period, spotted owl vocalizations are at a maximum, corresponding with average times of egg-laying (29 March) and fledging (early May to mid-June) (Forsman 1976), although spotted owls continue to vocalize well into early fall (personal observation).

Each timber sale study area was transected by driving Forest Service roads or by hiking cross-country. Calling stations were placed at intervals of 0.5 mi (0.8 km) along the transects (Jackman and Scott 1975, Gould 1974); no attempt was made to measure this distance straight-line. At each station, responses were solicited by playing a pre-recorded cassette tape (Forsman, U.S. Fish and Wildlife Service) of spotted owl calls, and occasionally by voice-calling. The tapes were played over an automobile cassette tape deck with external speakers, or a 400 mW portable Norelco tape deck, Model EL 3302.

The tape contained a mix of Location Calls (a four-hoot sequence), Contact Calls (a rising whistle), and Scolding Barks (a crow-like call) (Forsman 1976), and was played at about 4-minute intervals, interspersed by 4 minutes of silence, for approximately 15 min at each station. The field surveys were made between dawn and dusk, mostly between 2000 and 0300 hrs (Fig. 2).

The locations of all owls responding were noted on orthographic maps (scale 1:12,400) or location maps (scale 1:28,285) of each study area. Additional calling time or hiking was necessary to more accurately pinpoint some owl locations. Not all spotted owls heard represented a breeding pair. Breeding territories were recognized if 1) a male and female were both heard exchanging Location Calls (the male has a noticably deeper voice), indicating a pair-bond; 2) an unremitting series of Contact Calls were heard, which are given mostly by the female to maintain contact with her mate or young (Forsman 1976); 3) a Scolding Bark was heard, which is given mostly by the female during territorial encounters, or as a long-distance contact call between paired birds (Forsman 1976); or 4) a single owl giving Location Calls could not be pursuaded with intensive soliciting by taped calls to change location. Where any of these criteria was not met, the responding bird was assumed to be unpaired. In those rare cases where a breeding pair may have been recorded twice, previous calling stations were re-checked.

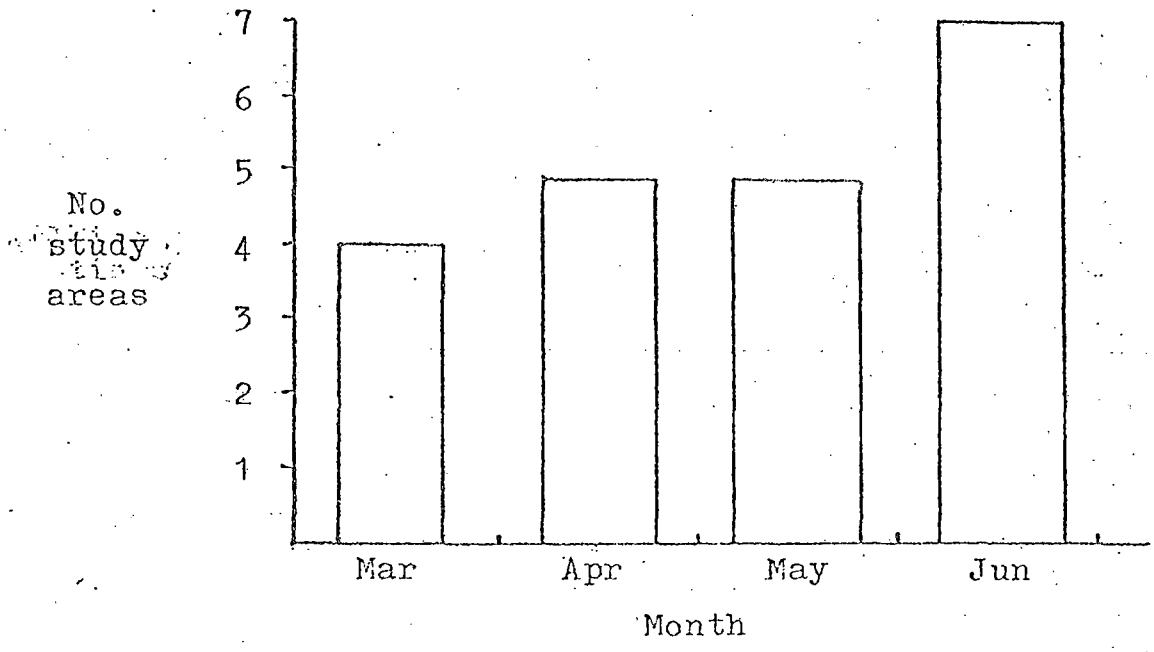


Fig. 1. Frequency distribution of study areas as a function of month.

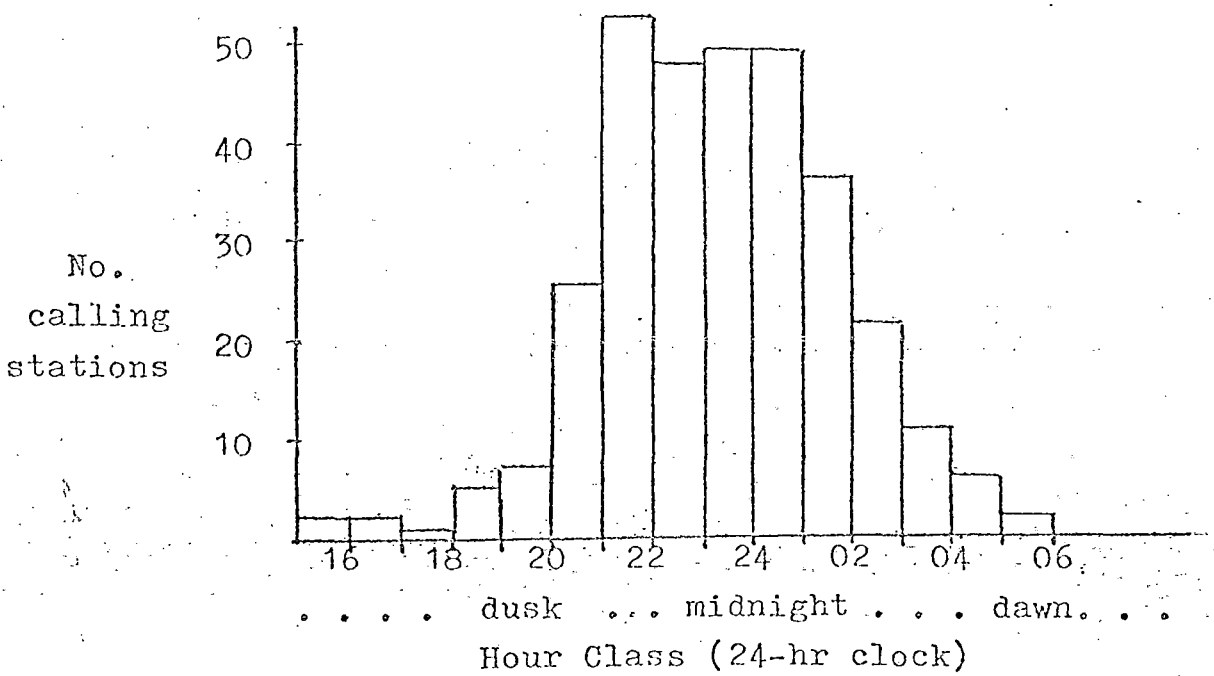


Fig. 2. Frequency distribution of sample calling stations as a function of hour of the day.

Three density indices of spotted owl territories were calculated from each survey: no. territories per calling station, per 100 min calling, and per mi or km transected. These three indices were calculated because the total no. of calling stations, average time spent at each station, total time spent calling, and total distance travelled in transects varied among the study areas, and factors biasing one index may not have biased all indices. The three indices were compared to one another, and the index of no. territories per mi or km was compared to similar indices from Forsman (1977) and Gould (1974).

Percent response (no. calling stations a response was elicited/ total no. calling stations) of spotted owls was assessed as a function of hour of the night.

Habitat Analyses

The indices of relative frequency from study areas located in different vegetation types (Kuchler 1977, and see Table 1) were compared to ascertain if the occurrance of spotted owl is influenced by general vegetation type.

Total and old growth acreages of all study areas were calculated from the orthographic or location maps, and from 1969 timber type maps. Seperate tallies were made of acreages of old growth douglas fir (timber types D5- through D5≡), and mature and old growth douglas fir (timber types D4= through D4≡, and all D5) (see U.S. Forest Service Manual and Table 2 for explanations of symbols), and percentages of each in the study areas were calculated.

Crude and ecological densities of breeding territories of spotted owls in all study areas were calculated. Crude density is defined here as the abundance of spotted owl territories in all timber types. It is estimated as the mean no. ac (or ha) per territory, or as no. territories per 1000 ac (400 ha), calculated from each study area and from all study areas combined.

Ecological density is defined here as the abundance of spotted owl territories in their optimum timber types (old growth or mature and old growth douglas fir). It is estimated as the mean no. old growth (or mature and old growth) ac (or ha) per territory, or as no. territories per 1000 old growth (or mature and old growth) ac (400 ha), calculated from each study area and from all study areas combined.

Crude density as calculated above was compared to crude density

as calculated from a modification of the "nearest-neighbor method" (Caughley 1977). When w is the square of the distanc in ft from one spotted owl territory to the next nearest known territory (see below), and $\bar{w}$ is the mean of a sample of n squared distances, the nearest-neighbor method estimated absolute crude density by the formula

$$N = \frac{n - 1}{\pi \bar{w} n} (43560 \text{ ft}^2/\text{ac})(1000 \text{ ac}),$$

where N = no. spotted owl territories per 1000 ac (400 ha). The inverse, i.e. no. ac (or ha) per territory, was estimated as 1000/N (or 400/N for ha). The nearest-neighbor method gives an estimate of crude rather than ecological density, because the distances measured between nearest territories transect all timber types.

The no. territories in each study area was correlated with 1) total acreage, 2) mature and/or old growth acreage, and 3) estimates of crude and ecological densities of spotted owl territories, from each study area. The relative frequency indices were correlated with percent mature and old growth of each study area.

Locations of the spotted owl territories on the field maps were assessed according to exposure and percent slope. Distances to the nearest known permanent water and to the next nearest known territory were also assessed and compared with similar measures taken by Forsman (1976) and Gould (1974).

Four regurgitated pellets taken from beneath spotted owl roosts or perch sites were dissected, and bones and hairs of prey items were identified. Implications of foraging habitats were discussed from this information and from data on food habits from the literature.

RESULTS AND DISCUSSION

Number of Territories and Individuals

Table 2 presents survey results of the timber sale study areas. Because of close proximity and thus ease of surveying, six study areas were censused as pairs (Dragon/Creek, Hastings/Skull, and Hetten/Shaw). A total of 54 spotted owl territories were discovered. The greatest number of territories was six, found in both the Jaws and Cape Horn surveys, although three of the six in the Jaws survey were outside the study area boundary. Pilot Ridge and Hetten/Shaw held no territories, but I feel that the one spotted owl discovered 30 June in the Pilot Ridge study area, drawn from a mature stand of douglas fir in a drainage complex to my calling, may have established a territory earlier in the season. Thus, estimates of relative frequency and density in the Pilot Ridge study area are based on one spotted owl territory.

A total of 68 individual spotted owls were found from the surveys, from which, accounting for territories representing a pair, I deduced a total of 113 individual spotted owls and 54 territories in the study areas. Thus, only five individuals (four percent) were unpaired, which roughly corresponds to Forsman's (1976) Oregon-based findings that only two individuals (one percent) of an inferred total of 244 were unpaired, but of course seasonal shifts of age-specific mortality rates and type of habitat surveyed may influence these percentages. Numbers of individuals (recorded and inferred) and territories of other owl species as well are presented in the Appendix.

Relative Frequency Indices

Relative frequency indices of spotted owl territories in all study areas are also presented in Table 2. A total of 315 calling stations, representing 5494 min (91.6 hr) of calling along 138.5 mi (222.8 km) of transects, yielded overall relative frequency indices of 0.17 territories per calling station, 0.98 per 100 min of calling, and 0.39 per mi (0.24 per km) transected.

Aside from the relative frequency indices of 0.00 in the Hetten/Shaw study areas, the lowest indices were found in the Spike study area and the highest in Winchuck. Thus, the no. territories per station ranged from 0.07 to 1.00; the no. territories per 100 min of calling ranged from 0.48 to 5.48; and the no. territories per mi (km) ranged from 0.15 (0.10) to 4.00 (2.49).

Table 2. Survey data of the timber sale (TS) study areas and relative frequency indices of spotted owl territories. (Also see Appendix.)

TS name	No. spotted owl terr. recorded	Extent of surveys: Total no. calling stations	Total no. minutes	Total no. mi (km)	Relative frequency indices: No. terr. per station	No. terr. per 100 min	No. terr. per mi (km)
Winchuck	4	4	73	1(1.6)	1.00	5.48	4.00(2.49)
Baker Flat	1	11	175	4.5(7.2)	0.09	0.57	0.22(0.14)
Jaws	6[a]	20	340	9(14.5)	0.30	1.76	0.67(0.41)
Butte Copter	2	6	94	2(3.2)	0.33	2.13	1.00(0.62)
Camp 7	4	13	205	6(9.7)	0.31	1.97	0.67(0.41)
Sugarloaf	1	7	112	2.5(4.0)	0.14	0.89	0.40(0.25)
Pen Vista	2	11	190	4.5(7.2)	0.18	1.05	0.44(0.28)
Line	3	10	180	4(6.4)	0.30	1.67	0.75(0.47)
Wilson	4	28	536	13(20.9)	0.14	0.75	0.31(0.19)
Dragon/Ck.	4	33	720	15.5(24.9)	0.12	0.57	0.26(0.16)
Cape Horn	6	22	385	10(16.1)	0.27	1.56	0.60(0.37)
Butte	4	18	337	6.5(10.5)	0.22	1.19	0.62(0.39)
Maple	2	15	239	6.5(10.5)	0.13	0.84	0.31(0.19)
China	3	30	510	14.5(23.3)	0.10	0.59	0.21( )
Willow	1	3	59	1(1.6)	0.33	1.70	1.00( )
East	2	19	325	9(14.5)	0.11	0.62	0.22(0.14)
Spike	1	14	210	6.5(10.5)	0.07	0.48	0.15(0.10)
Pilot Ridge	0(1)[b]	10	153	4.5(7.2)	0.10[b]	0.65[b]	0.22(0.14)
Hastings/Sk.	1	9	155	4(6.4)	0.11	0.65	0.25(0.16)
Brown	3	21	341	9.5(15.3)	0.14	0.88	0.32(0.20)
Hetten/Shaw	0	11	173	4.5(7.2)	0.00	0.00	0.00(0.00)
Totals	54	315	5494	138.5(222.8)	0.17[c]	0.98[c]	0.39(0.24)

[a]Three of these are outside the Jaws TS boundary; the density indices are based on all six territories.

[b]One territory is inferred (see text for explanation); the density indices are based on one territory.

[c]Calculated from totals, not averaged of all study areas.

The three relative frequency indices correlated to one another significantly (all at $P < .001$): no. territories per station against no. territories per 100 min ($r = 0.996$, Fig. 3); no. territories per 100 min against no. territories per mi or km ($r = 0.972$, Fig. 4); and no. territories per station against no. territories per mi or km ($r = 0.962$, Fig. 5). Because of these highly significant correlations, any one relative frequency index, e.g. no. territories per mi or km as used below, may be employed as representative of the other two indices.

Gould's (1974) surveys of northern California counties yielded overall estimates of no. spotted owl territories per mi (km) of 0.23 (0.14) in Humboldt Co., 0.44 (0.27) in Trinity Co., and 0.16 (0.10) in Siskiyou Co. Gould's (1974) overall relative frequency in Six Rivers NF (n = 24.7 mi or 39.7 km) was 0.24 territories per mi (0.15 per km), which is an estimate comparable to his individual county surveys, but which is lower than his state-wide average (n = 549 mi or 884 km) of 0.32 territories per mi (0.20 per km). These figures are somewhat lower than but comparable to the overall mean (0.39 territories per mi or 0.24 per km) and range (0.15-4.00 per mi or 0.10-2.49 per km) from this study.

In douglas fir-western hemlock (Tsuga heterophylla) stands in western Oregon, Forsman (1977) discovered 0.58 spotted owl territories per mi (0.36 per km) in old growth, and 0.05 territories per mi (0.03 per km) in second growth. The overall average from this study falls mid-way between these values, but comparisons should be made with caution; Forsman's Oregon survey areas generally represented a different vegetation type than this study's survey areas. Also, most of this study's survey areas were much more mosaic in stand structure, owing to timber harvesting, unlike the more extensive tracts of old growth and thinned second growth in the Oregon survey areas.

Calling Responsiveness

Most calling was done between dusk and dawn (see Fig. 2). Spotted owl response over this time span exhibited a roughly trimodal curve (Fig. 6), with peak responses at just a little after dusk, a little after midnight, and just before dawn.

Spotted owls forage mostly nocturnally, except for some occasional, opportunistic diurnal feeding (Forsman 1976), but peak activity periods have not been determined; perhaps this trimodality reflects activity peaks. From a coastal redwood forest located west of Six Rivers NF, Erickson (no date) reported overall peaks of responses during midnight and dawn from six owl species, but the data on spotted owl responses, although similar, were too sparse for conclusions. Overall responsiveness

Fig. 3. Comparison of relative frequency indices: no. spotted owl territories per 100 min calling as a function of no. territories per calling station.

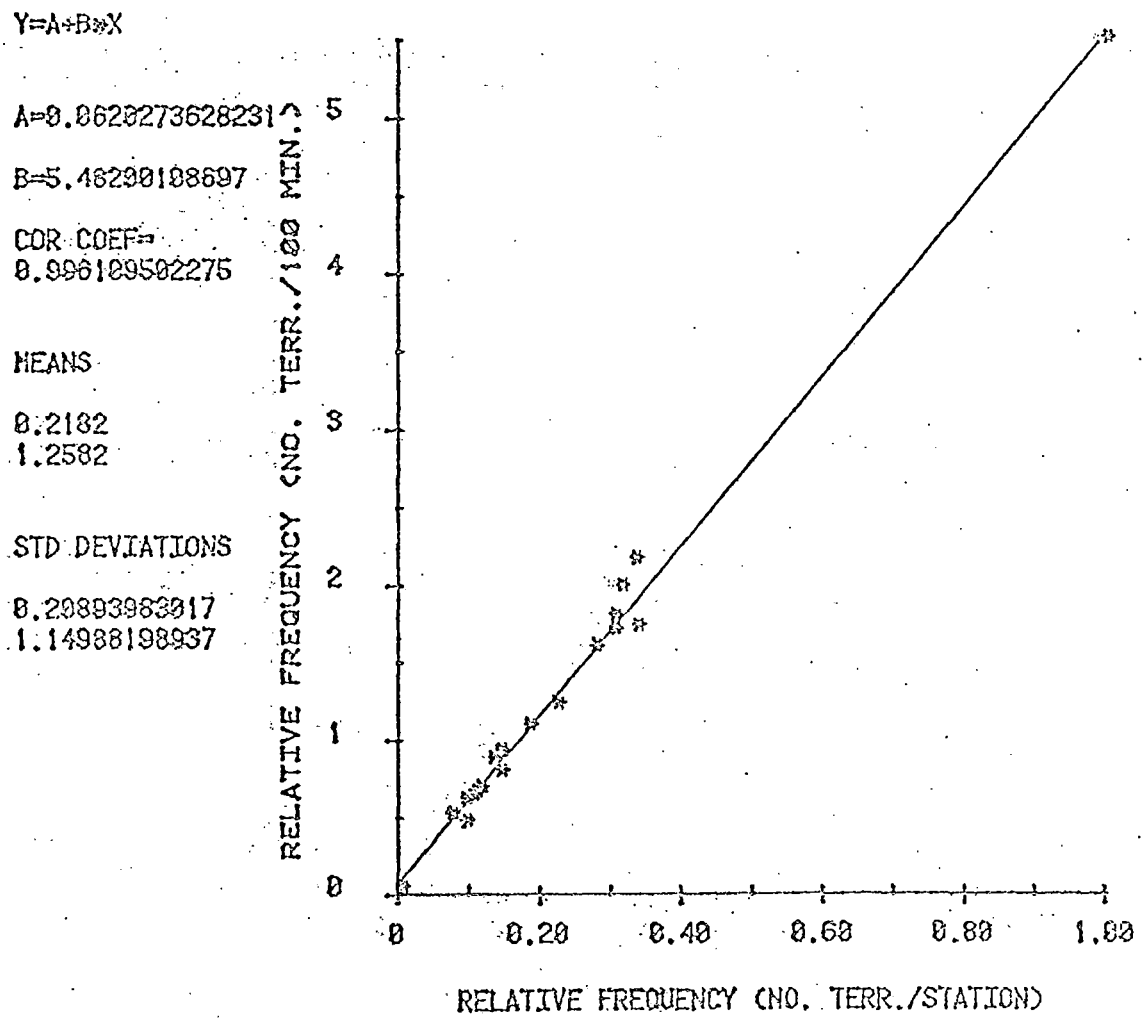


Fig. 4. Comparison of relative frequency indices: no. spotted owl territories per km transected as a function of no. territories per 100 min calling.

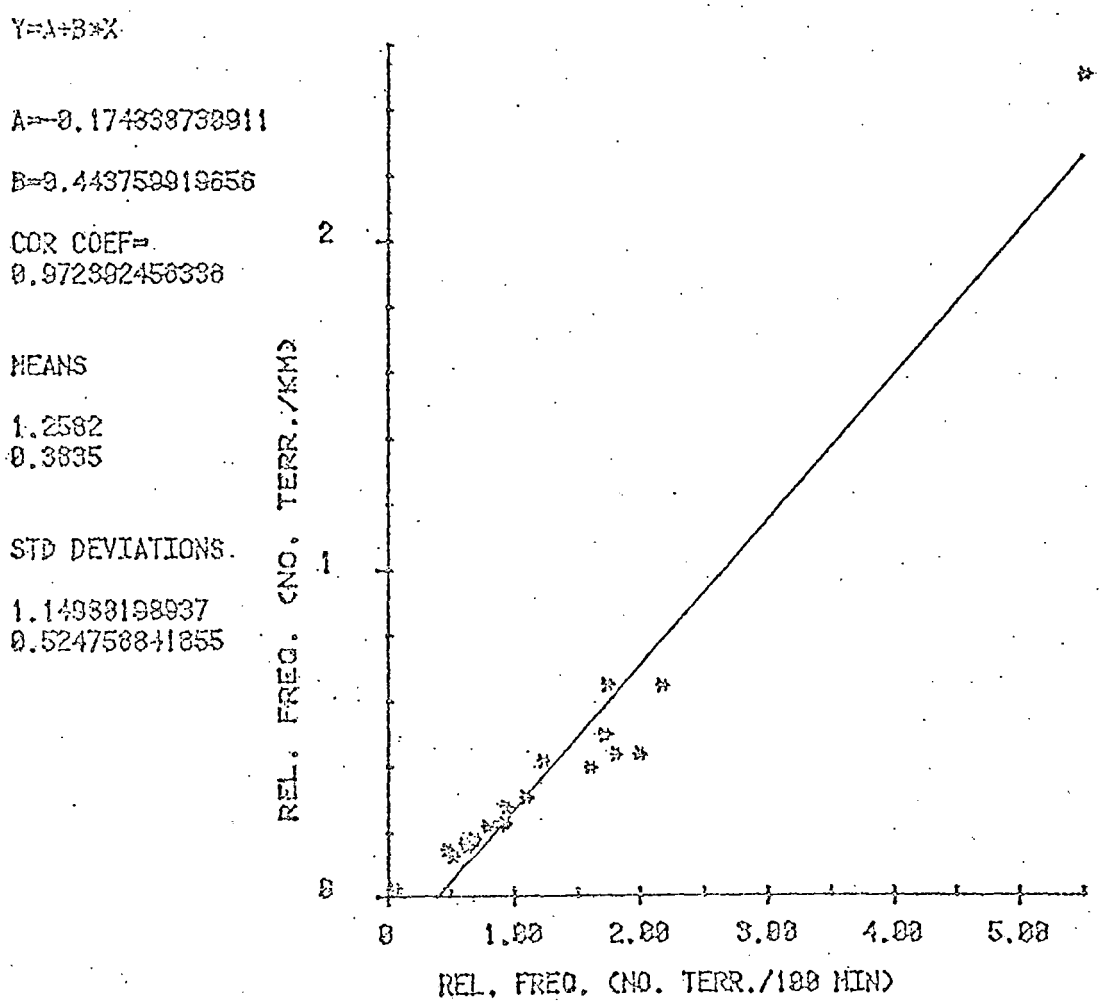
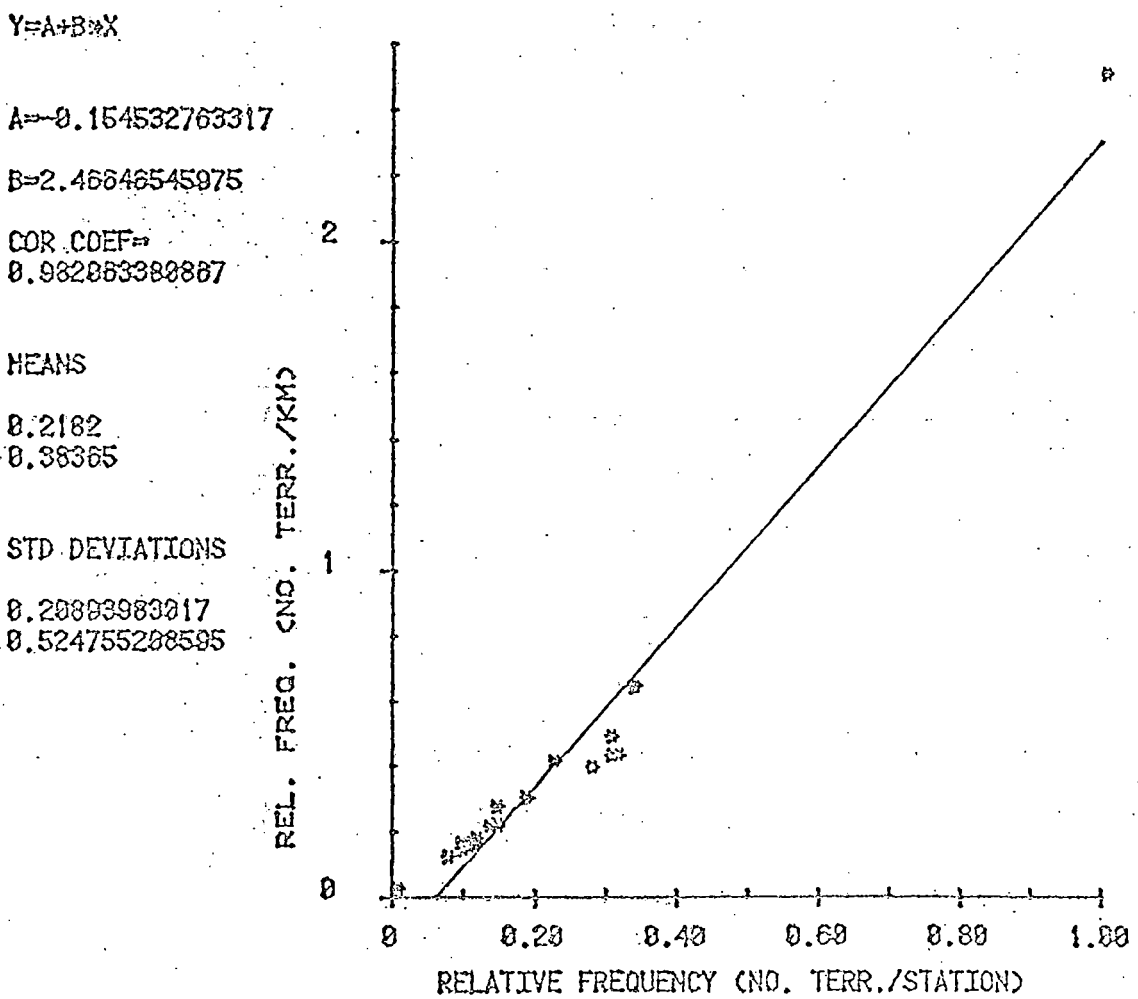


Fig. 5. Comparison of relative frequency indices: no. spotted owl territories per km transected as a function of no. territories per calling station.



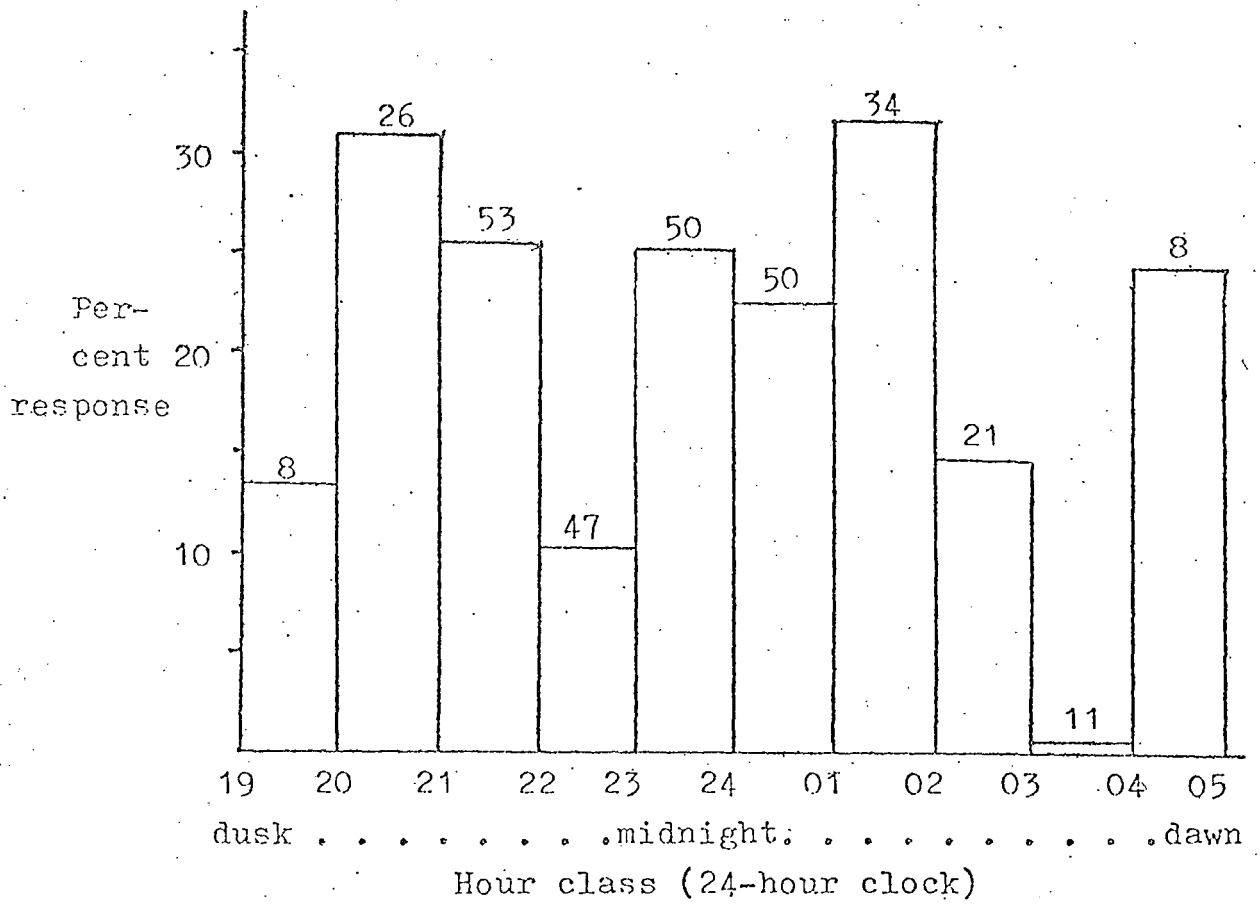


Fig. 6. Percent response (no. calling stations a response was elicited/total no. calling stations) of spotted owls as a function of hour of the day. Data above bars are total no. of calling stations of each hour class.

of spotted owls from this study's 315 calling stations was 22 percent.

Vegetation Types

Most surveys were conducted and most of the spotted owl territories were discovered in two general vegetation types: Klamath montane forest with douglas fir and mixed evergreen forest with chinquapin (see Tables 1 and 3). No spotted owls were found in Oregon oak forest, and three territories were found in one survey in Coast Range montane forest. There was no significant difference in the relative frequencies of spotted owl territories per mi or km between Klamath montane forest, mixed evergreen forest, and Coast Range montane forest (Mann-Whitney U, $P > 0.20$). Because of the extensive mosaic nature of most timber sale study areas, with clear-cut blocks in various seres interspersing islands of old and second growth, comparisons of relative frequencies between seral stages of different study areas cannot be made.

Zarn (1974), after Forsman, wrote that spotted owls tend to prefer the dense, old growth conifer stands found in the Mixed Conifer (Pinus - Pseudotsuga - Calocedrus - Abies) Zone (Franklin and Dyrness 1973) of the Cascade Range of southwest Oregon, and in the extensive Tsuga heterophylla Zone (Franklin and Dyrness 1973) of the Coast and Cascade Ranges of western Oregon and Washington. The former of these vegetation types corresponds to Küchler's (1977) Coast Range montane forest, in which I found spotted owl territories of relative frequencies comparable to Zarn's (1974) statement and Forsman's (1976) findings. The latter of the vegetation types corresponds to Küchler's (1966) cedar-hemlock-douglas fir forest, extensive in the Cascade Ranges of Oregon and Washington, and also to Küchler's (1977) Klamath montane forest with douglas fir, which is the southernmost representation of the Tsuga heterophylla Zone intruding into northwestern California. Again, spotted owl territories were found in Klamath montane forest with douglas fir in relative frequencies comparable to Zarn's (1974) statement and Forsman's (1976, 1977) findings.

Küchler's (1977) mixed evergreen forest with chinquapin is basically a California phenomenon and has therefore not been as extensively surveyed in Oregon for spotted owls. However, Forsman (1976) found spotted owls throughout the Mixed Evergreen and Mixed Conifer Zones (Franklin and Dyrness 1973) in the Siskiyou Mountains and southern Cascade Range, which are comparable in part to Kuchler's (1977) mixed evergreen forest with chinquapin.

Gould (1977) reported that douglas fir was the dominant tree

Table 3. Relative frequencies (no. territories per mi or km) of spotted owls in four major vegetation types. See text for comparisons. These data omit the Jaws timber sale study area, because the vegetation type is transitional.

Vegetation type[a]	Total no. territories	Total mi (km) of surveys	No. terr. per mi (km)
12	16	45.5(73.2)	0.35(0.22)
14	3	9.5(15.3)	0.32(0.20)
20	0	4.5(7.2)	0.00(0.00)
21	30	70.0(112.6)	0.43(0.27)

[a]Küchler's (1977) vegetation types (see text for descriptions):
12 - Klamath montane forest with douglas fir
14 - Coast Range montane forest
20 - Oregon oak forest
21 - Mixed evergreen forest with chinquapin

species where spotted owls were found in mixed evergreen forests in the north coast area of California, and that at about 16 percent of the sites yellow pine was dominant.

In summary, spotted owls seem pervasive throughout most coniferous vegetation types in the Coast and Cascade Ranges. Only where dense stands of old growth conifers do not exist, as in the Oregon oak forest (Küchler 1977) surveyed in this study, does the relative frequency of spotted owls drastically decline. Gould (1977) also found that California black oak was incapable by itself of providing adequate habitat for spotted owls.

Crude and Ecological Densities

Table 4 presents total, mature and old growth, and old growth area of the timber sale study areas. Crude and ecological densities of spotted owl territories in each study area are presented in Table 5. Crude density in terms of no. territories per 1000 total ac (400 ha) ranged from 0.28 in the Butte and Spike study areas to 1.83 in the Camp Seven study area. Ecological density in terms of no. territories per 1000 mature and old growth ac (400 ha) ranged from 0.56 in the Maple study area to 4.98 in the Winchuck study area. Ecological density in terms of no. territories per 1000 old growth ac (400 ha) ranged from 1.94 in the Maple study area to 63.49 in the Butte study area; this latter figure is tremendously high because of the paucity of old growth in the Butte study area.

All study areas combined represented 82,627 ac (33,439 ha), of which 29,848 ac (12,079 ha) were mature and old growth, and 10,592 ac (4287 ha) were just old growth (Table 4). Thus, the overall crude density based on all timber types was 1460 total ac (591 ha) per territory, or 0.65 territories per 1000 total ac (400 ha). The overall ecological density based on mature and old growth was 585 ac (237 ha) per territory, or 1.71 territories per 1000 ac (400 ha). The overall ecological density based only on old growth was 208 ac (84 ha) per territory, or 4.8 territories per 1000 ac (400 ha).

Which of these density estimates are the more meaningful or useful? One way to assess the degree of statistical dispersion of the density estimates in the study areas is to assess the coefficient of variation (CV = SD/mean). However, CV was not significantly different between the density estimates based on no. total ac per territory (CV = 0.56), no. mature and old growth ac per territory (CV = 0.61), and no. old growth ac per territory (CV = 0.59).

The topographic distribution of the timber types in the study areas reveals much. Mature and old growth stands often occur

Table 4. Total, mature, and old growth acres (hectares in parentheses), and percent mature and old growth, of the timber sales (TS) study areas.

TS name	Total area	Mature and old growth area[a]	Percent mature and old growth	Old growth area[a]	Percent old growth
Winchuck	2261(915)[b]	804(325)	36	459(186)	20
Baker Flat	2866(1160)	1173(475)	41	517(209)	18
Jaws	3975(1609)	817(331)	21	283(115)	7
Butte Copter	2540(1028)	1895(767)	75	1160(469)	46
Camp Seven	2142(887)	954(386)	45	821(332)	38
Sugarloaf	807(327)	720(291)	89	429(174)	53
Pen Vista	4522(1831)	2990(1210)	66	1101(446)	24
Line	3753(1519)	---[c]	--[c]	---[c]	--[c]
Wilson	3575(1447)	1268(513)	35	611(247)	17
Dragon/Creek	7980(3231)	2669(1080)	33	604(244)	8
Cape Horn	5066(2051)	2709(1096)	54	555(225)	11
Butte	14366(5816)	1857(752)	13	63(25)	0.4
Maple	4805(1945)	3578(1448)	74	1030(417)	21
China	4942(2001)	2194(888)	44	140(57)	3
Willow	1833(742)	802(325)	44	190(77)	10
East	3530(1429)	1090(441)	31	593(240)	17
Spike	3586(1452)	1291(522)	36	229(93)	6
Pilot Ridge	817(331)	432(175)	53	432(175)	53
Hastings/Skull	3193(1292)	564(228)	18	331(134)	10
Brown	4200(1700)	1541(624)	37	754(305)	18
Hetten/Shaw	1868(756)	500?(202?)	27?	290(117)	16
Totals[d]	78874(31920)	29848(12079)	38	10592(4287)	13

[a]Refers to standard US Forest Service coding for timber stands, in which letters designate canopy tree species, numbers refer to age class, and dashed lines or bars indicate percent crown closure. For example, as used here:
D - douglas fir overstory
4 - mature; 5 - old growth
- 0-20%; = 20-40%; ≡ 40-70%; ≣ 70-100%
As used above, "mature" refers to D4= through D4≣, and "old growth" refers to all D5.

[b]Includes 1234 ac (499 ha) of RARE II (roadless area) country, in which three territories were found; actual timber sale size was 1027 ac (416 ha).

[c]No data.

[d]Excluding Line.

Table 5. Crude and ecological densities of breeding territories of spotted owls, as ac (ha) per territory and no. territories per 1000 ac (400 ha), in 24 timber sale (TS) study areas on the Six Rivers National Forest. For reasons given in the text, no. mature and old growth ac per territory (column four) is the most useful estimate.

	Crude density		Ecological density			
	Based on all timber types		Based on mature and old growth[a]		Based on old growth[a]	
TS name	No. ac (ha) per terr.	No. terr./ 1000 ac (400 ha)	No. ac (ha) per terr.	No. terr./ 1000 ac (400 ha)	No. ac(ha) per terr.	No. terr./ 1000 ac (400 ha)
Winchuck	565(229)[b]	1.77[b]	201(81)[b]	4.98[b]	115(47)[b]	8.71[b]
Baker Flat	2866(1160)	0.35	1173(475)	0.85	517(209)	1.93
Jaws	1325(536)	0.76	272(110)	0.76	94(38)	10.60
Butte Copter	1270(514)	0.79	948(384)	1.06	580(235)	1.72
Camp Seven	548(222)	1.83	239(97)	4.19	205(83)	4.87
Sugarloaf	807(327)	1.24	720(291)	1.39	429(174)	2.33
Pen Vista	2261(915)	0.44	1495(605)	0.67	551(223)	1.82
Line	1251(506)	0.80	---[c]	---[c]	---[c]	---[c]
Wilson	894(362)	1.12	317(128)	3.16	153(62)	6.55
Dragon/Creek	1995(807)	0.38	890(360)	1.12	201(81)	4.97
Cape Horn	844(342)	1.18	452(183)	2.22	93(38)	10.81
Butte	3592(1454)	0.28	464(188)	2.15	16(6)	63.49
Maple	2403(973)	0.42	1789(724)	0.56	515(209)	1.94
China	1647(667)	0.61	731(296)	1.37	47(19)	21.43
Willow	1833(742)	0.55	802(325)	1.25	190(77)	5.26
East	1765(715)	0.57	545(221)	1.84	297(120)	3.37
Spike	3586(1452)	0.28	1291(523)	0.78	229(93)	4.37
Pilot Ridge	817(331)[d]	1.22[d]	432(175)[d]	2.32[d]	432(175)[d]	2.32[d]
Hastings/Skull	3193(1293)	0.31	564(228)	1.77	331(134)	3.02
Brown	1400(567)	0.71	514(208)	1.95	251(102)	3.98
Hetten/Shaw	---	0.00	---	0.00	---	0.00

[a]See Table 4, note a.

[b]See Table 4, note b.

[c]No data.

[d]Densities are based on one inferred territory (see text).

contiguous with one another, whereas other timber types were interspersed in various mosaic patterns mostly according to recent timber harvests. Spotted owls using an old growth douglas fir stand would probably more likely be apt to use contiguous stands of at least moderately dense mature douglas fir (D4= to D4≡) than other timber types. Indeed, almost all spotted owls encountered during the surveys occurred in either mature or old growth stands. Also, spotted owls prefer to forage in the denser canopies of mature and old growth stands (Forsman 1976, Jackman and Scott 1975). Thus, the most useful estimate of density, which would best facilitate management, is based on mature and old growth timber types. The Management section of this report discusses the implications of these estimates.

Overall crude density, calculated by the "nearest-neighbor method" (Caughley 1977) (see below for a discussion of spacing of territories), was 3195 ac (1293 ha) per territory, or 0.31 territories per 1000 ac (400 ha). This is lower than the above estimate of crude density based only on total area and total no. territories (1460 total ac or 591 ha per territory, or 0.65 territories per 1000 ac), because measurements between "nearest-neighbor" territories were made only within the study area boundaries. The existence of potentially closer (unsurveyed) territories just outside the boundaries would increase the estimate to a more comparable value.

Gould (1974,1977) discovered a significant concentration of spotted owls in the South Fork of the Trinity River drainage along the east slope of South Fork Mountain in south Trinity County, California, corresponding to the south eastern region of Six Rivers NF. In this area, 16 spotted owl pairs were found in an area of about 125 sq mi (328 sq km), 30 mi long by 2-6 mi wide (48 km long by 3-10 km wide), thus with a crude density of 0.20 territories per 1000 ac (400 ha). The crude density estimates from this study indicate slightly higher concentrations in this general region than Gould's data indicated.

In a particularly large concentration of old growth in Benton County, Oregon, in the Coast Range, Forsman (1976) found four pairs in an area of roughly 15 sq mi (39 sq km), thus with a crude density of 0.42 territories per 1000 ac (400 ha). In Lane County, he found six pairs in one township, or 0.26 territories per 1000 ac. In other areas in the Coast Range where private inholdings were extensive or where old growth forests on federal lands were depleted, he found densities averaging less than two pairs per township, or less than 0.09 territories per 1000 ac. Densities of spotted owl territories in the Siskiyou Mountains in Oregon, restricted primarily to uncut, old growth forests on federal land, ranged

up to three to four pairs per township, or 0.13 to 0.17 territories per 1000 ac. All of these figures are lower than the estimate of overall crude density from this study, but are comparable to estimates of many study areas individually.

Each study area did not represent an ecological unit; the boundaries were largely political rather than ecological in nature. However, since most of the study areas contained at least a few whole upper drainages, correlations were made between density of spotted owl territories and study area size. The no. territories in the study areas correlated poorly with total acres of each study area (Fig 7; $r = 0.427$, $0.10 > P > 0.05$), and with mature and old growth acres of each study area (Fig. 8; $r = 0.317$, $0.20 > P > 0.10$). Although the correlations were poor, as would be expected with such a heterogeneous assemblege of study areas with various histories of timber harvesting, the slopes of both regressions were positive. Such positive slopes reflect MacArthur and MacArthur's (1961) notion that bird species diversity, including population size, varies according to the size of a sample area. Quite simply, the greater the area, the more territories of spotted owls, if the critical nesting habitat is available. In the case of the Butte study area, which of 14,366 total ac (5816 ha) only 13 percent was mature and old growth and only 0.4 percent was old growth, large total size did not encourage more territories.

The no. territories in each study area correlated with crude breeding density (no. territories per 1000 total ac) significantly (Fig. 9; $r = 0.511$, $0.02 > P > 0.01$), and highly significantly if the anomolously large Butte study area was excluded from the correlation ($r = 0.596$, $0.01 > P > 0.005$). Also, the no. territories correlated significantly with ecological density (no. territories per 1000 mature and old growth ac) (Fig. 10; $r = 0.539$, $0.02 > P > 0.01$). Likewise, the no. territories correlated significantly with crude density expressed as no. total ac per territory (Fig. 11; $r = -0.581$; $0.02 > P > 0.01$, excluding Butte study area as above), and with ecological density expressed as no. mature and old growth acres per territory (Fig. 12; $r = -0.492$, $0.05 > P > 0.02$).

The importance of the above regressions lies in their biological interpretation. The significant correlations between the no. territories and crude or ecological density imply a crowding effect based on overlapping home ranges. Limits to this effect have important management implications, as discussed below.

An important distinction must be made between numbers or densities of spotted owl territories and numbers or densities

Fig. 7. No. spotted owl territories as a function of total acreage of the timber sale study areas (n = 21).

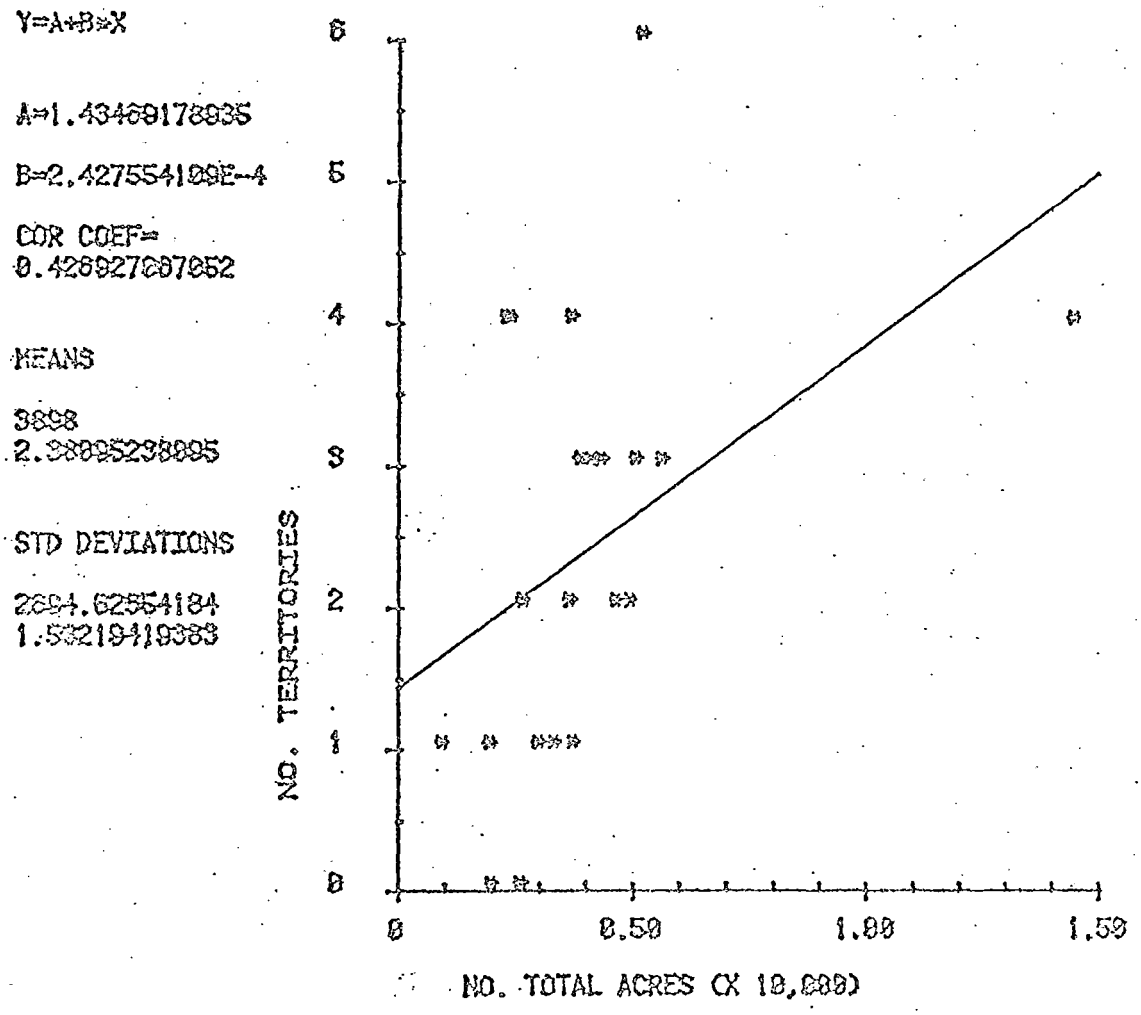


Fig. 8. No. spotted owl territories as a function of mature and old growth acreage of the timber sale study areas (n = 19).

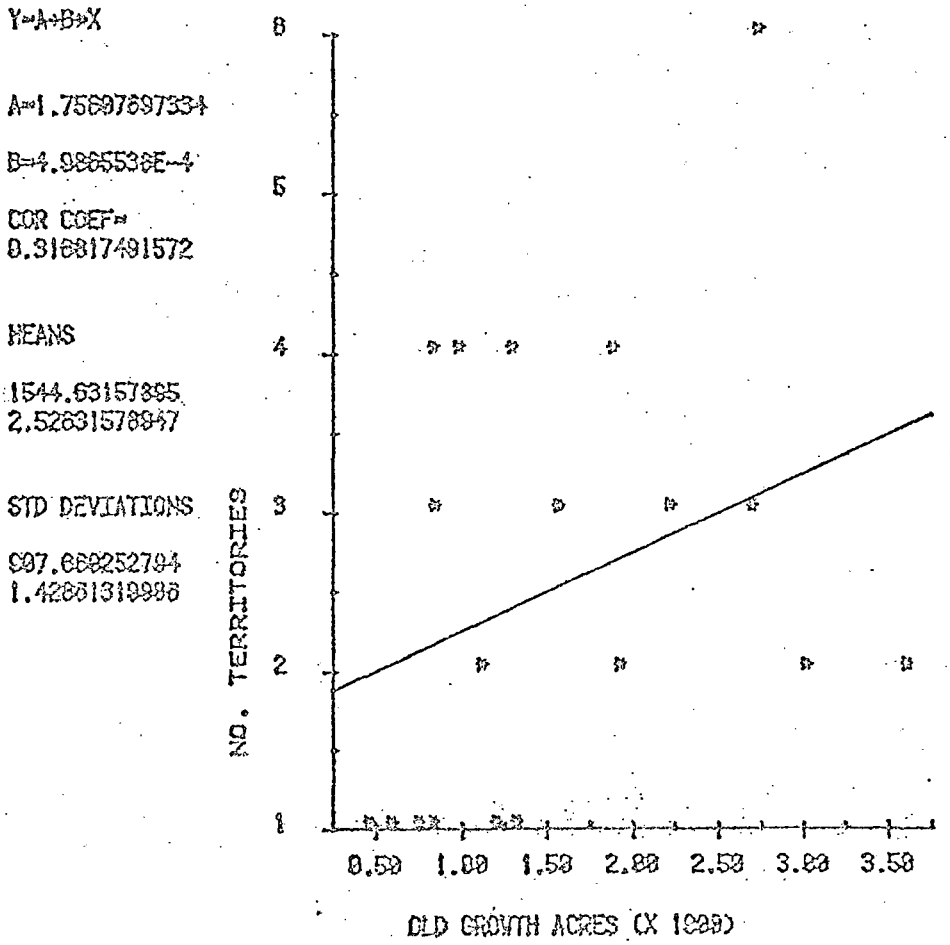


Fig. 9. No. spotted owl territories as a function of crude density of spotted owl territories (no. territories per 1000 total ac) (n = 21).

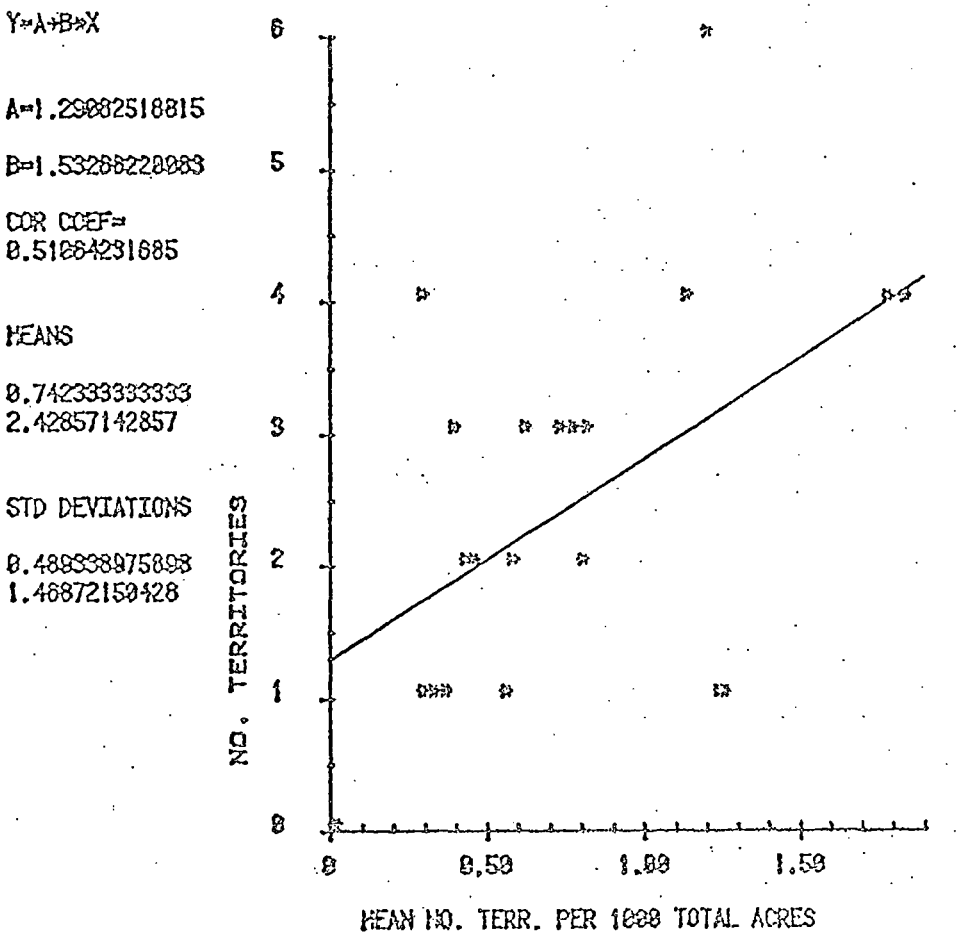


Fig. 10. No. spotted owl territories as a function of ecological density of spotted owl territories (no. territories per 1000 mature and old growth ac) (n = 19).

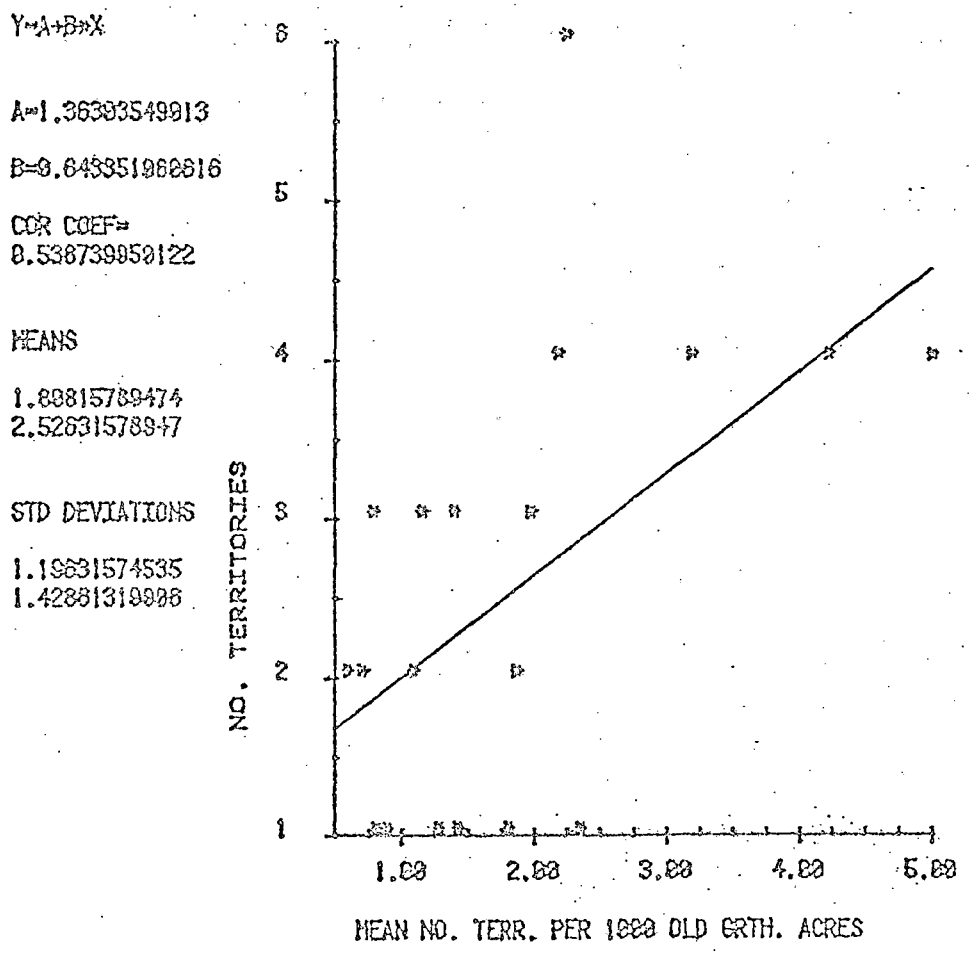


Fig. 11. No. spotted owl territories as a function of crude density of spotted owl territories (no. total ac per territory) (n = 19).

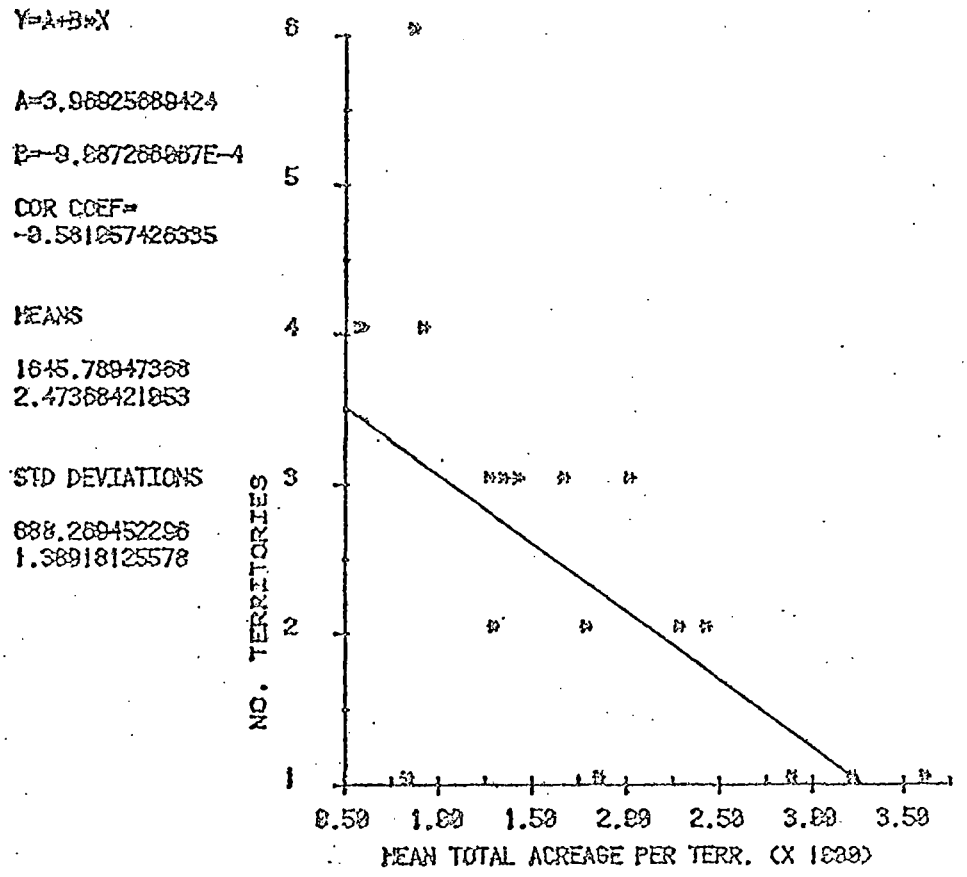
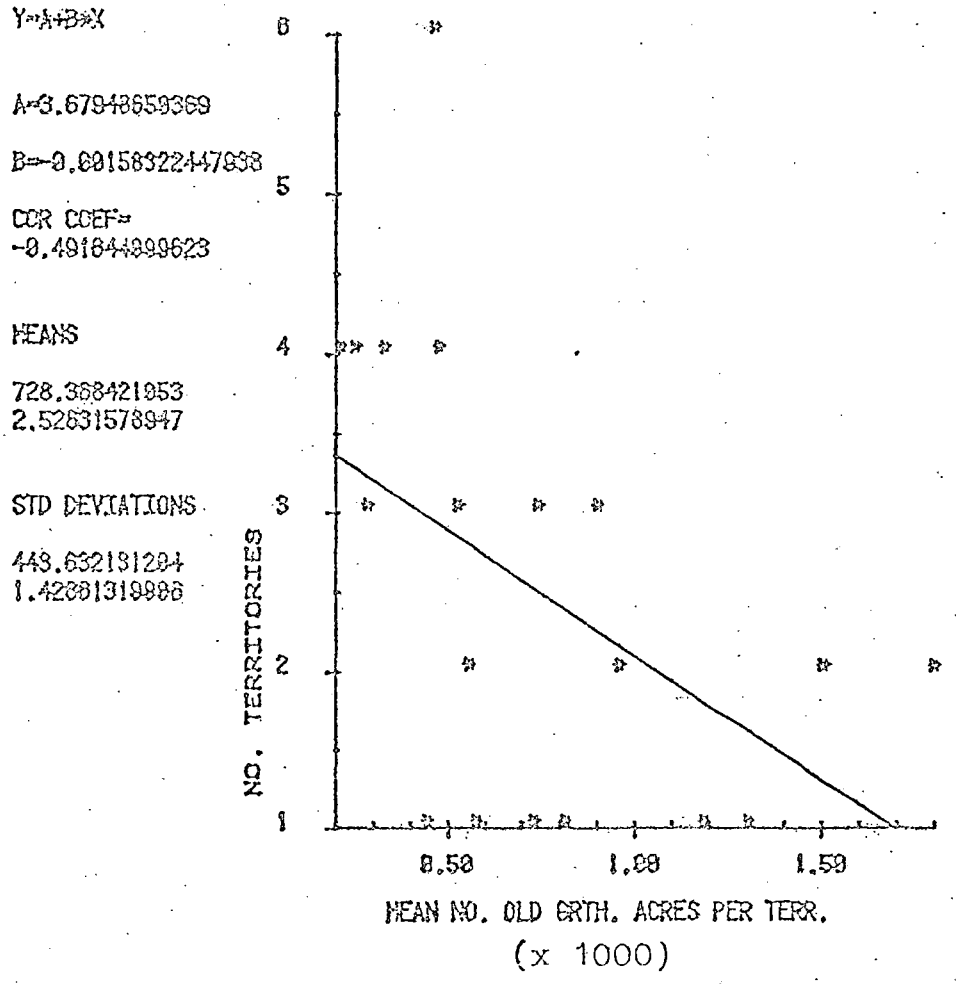


Fig. 12. No. spotted owl territories as a function of ecological density of spotted owl territories (no. mature and old growth ac per territory) (n = 19).



of nest trees per se. Because active calling by tape or voice will draw owls toward the caller, estimates of densities of territories can only be used a ceilings of estimates of actual nest densities. Also, and more importantly, densities expressed in terms of no. ac per territory in no way refer to either territory (defended space) size or home range size.

Relative frequency (no. territories per calling station) showed no correlation with percent mature and old growth in the study areas (Fig. 13; $r = -0.049$, $P > 0.50$). This independency probably reflects the spotted owl's mobility and thus propensity to draw near and respond to calls, despite the stand structure in an area.

Habitat Parameters

Since spotted owls may move toward a caller and thus encounter different timber stands or topographies, the topographic nature of where each territory was discovered may differ significantly from that of the nest site per se (Forsman, pers. comm.). With this caveat, Fig. 14 presents data on exposure and percent slope of spotted owl territories as indicated on the field maps, and also similar data from Forsman (1976) and Gould (1974); only Forsman's data represent nest sites.

Forsman's (1976) data showed a preference by spotted owls for north exposures, as did Gould's (1974) data. Data from this study runs counter to these trends by indicating a preference by spotted owls for south and east exposures. Again, the indications of preference may be spurious. However, many owls were located from this study in island residua of mature and old growth stands of douglas fir; some of these residual stands were oriented to a south or west exposure, a suboptimal condition according to Forsman's (1976) or Gould's (1974) data. This may indicate that spotted owls will use stands with southern exposures, despite the lesser thermal cover than with northern exposures, if such stands are all that are available.

The data on percent slope from this study probably reflect the general topographic nature of the study areas more than any preference by spotted owls, as slopes of 25-75 percent, especially 25-50 percent, were quite common.

Distances of 48 territories to the nearest known permanent water averaged 0.27 mi (0.44 km) and ranged 0-1.00 mi (0-1.61 km). These are somewhat higher estimates than the average 0.15 mi (0.24 km) and range 0-0.6 mi (0-0.97 km) from Gould's (1974) survey of 53 territories in the North Coast California douglas

Fig. 13. Relative frequency of spotted owl territories (no. territories per calling station) as a function of percent mature and old growth in the timber sale study areas (n = 19).

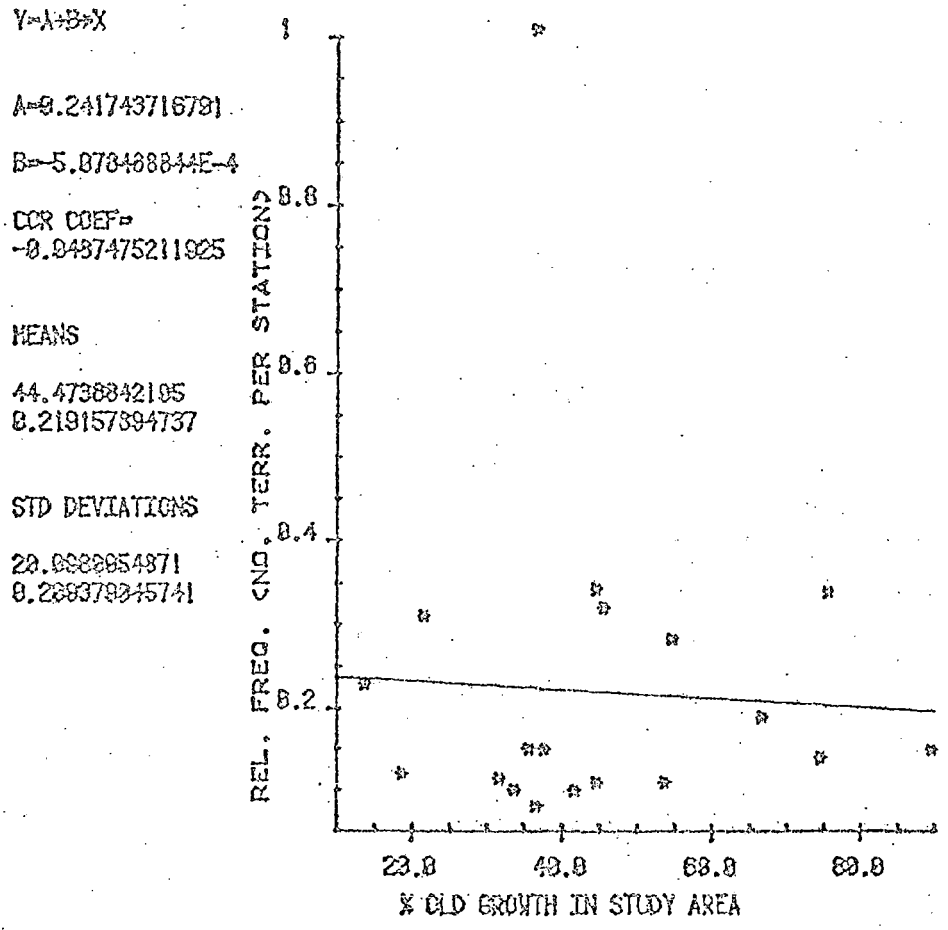
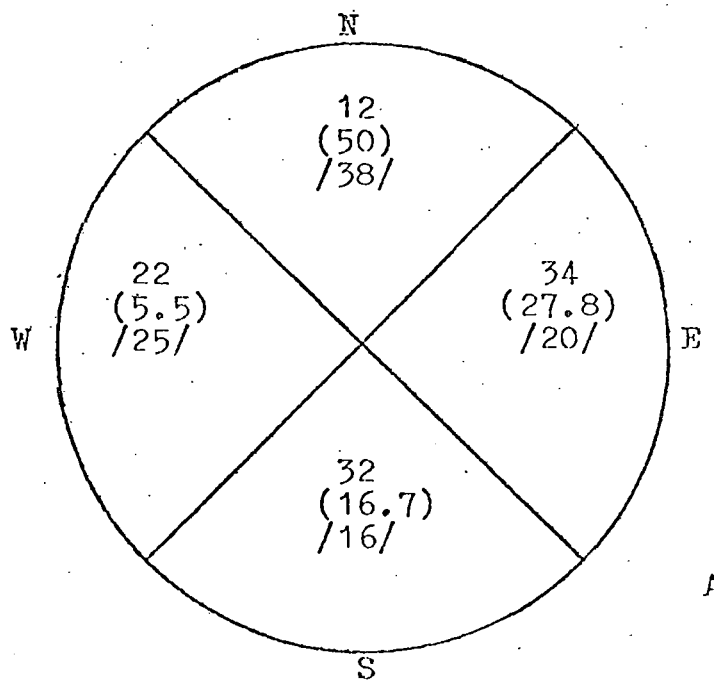
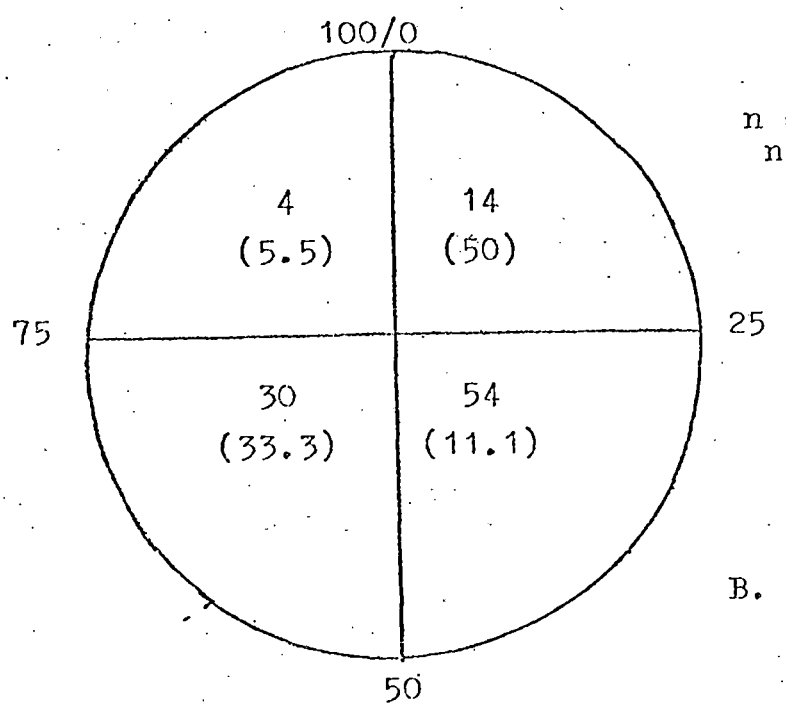


Fig. 14. Exposure and percent slope of spotted owl territories as located in the field. All numbers within circles refer to percent of territories or nests in each category. Numbers within parentheses () refer to percent of nest sites from Forsman (1976). Numbers within slask marks // refer to percent of territory sites from Gould (1974).[a]



n = 50, this study
n = 18, Forsman (1976)
n = 51, Gould (1974)

A. Exposure



n = 51, this study
n = 18, Forsman (1976)

B. Percent slope

[a]Gould's (1974) data is from his "North Coast douglas fir" survey only.

fir region, and than the average 0.16 mi (0.25 km) and range 0-0.9 mi (0-1.4 km) from Forsman's (1976) analyses of 18 nest sites in Oregon. All three studies indicate modes in the frequency of territory or nest sites corresponding to locations immediately adjacent to, and about 0.12 mi (0.19 km) from, permanent water (Table 6). The former mode may indicate a preference by spotted owls for the better thermal cover and greater abundance of larger potential nest trees located adjacent to permanent water.

Spacing of Territories

Distances of 26 territories to the next nearest known territory averaged 1.09 mi (1.75 km) and ranged 0.27-2.82 mi (0.43-4.54 km), and 61 percent of the minimum distances between pairs were from 0.62 to 1.24 mi (1.00 to 2.00 km) (Fig. 15). The two anomolously lowest minimum distances, 0.27 and 0.32 mi (0.44 and 0.51 km), occurred between two pairs of spotted owls that were each located along stream courses in old growth douglas fir. The optimal habitat of streamside old growth thus seems conducive to higher densities of spotted owl territories.

Marshall (1942) indicated intervals of 1-2 mi (1.6-3.2 km) between pairs in suitable habitat. Gould (1974) reported minimum distances between spotted owl territories averaging 2.2 mi (3.5 km) and ranging 0.1-7+ mi (0.2-11+ km), and that 63 percent of 70 minimum distances between pairs were from 0.8 to 1.8 mi (1.3 to 2.9 km), statewide. I concur with Gould's (1974) warning that "it must be noted that the minimum distance between adjacent pairs. . .is not the minimum internest distance nor the minimum distance between day-time perch sites." However, the data from this study of average minimum distances, density of territories, and relative frequencies of territories, all indicate higher concentrations of spotted owl territories on the Six Rivers National Forest than Gould (1974) found statewide or in the four north coast counties of California, implying a major population concentration, as Gould (1974,1977) found in south Trinity County.

Food Habits and Foraging Habitats

Four regurgitated spotted owl pellets contained three identifiable prey items: California vole (*Microtus californicus*), wood rat (*Neotoma fuscipes* or *N. cinerea*), and pinyon mouse (*Peromyscus truei*).

The literature, as reviewed by Forsman (1976) and Zarn (1974) indicates that spotted owls are highly euryphagous, i.e. take

Table 6. Distances from spotted owl breeding territories (this study) and nest sites (Forsman 1976) to the nearest permanent water.

Distance in ft (m)		Frequency (percent)	
		This study	Forsman (1976)
0-165	(0-50)	6 (13)[a]	5 (28)[a]
165-328	(50-100)	4 (8)	2 (11)
328-656	(100-200)	12 (25)[a]	6 (33)[a]
656-984	(200-300)	9 (19)	2 (11)
984-1641	(300-500)	4 (8)	1 (5.6)
1641-3281	(500-1000)	8 (17)	1 (5.6)
>3281	(> 1000)	5 (10)	1 (5.6)
Totals		48 (100)	18 (100)

[a]Salient modes (see text), as also appeared in Gould's (1974) data.

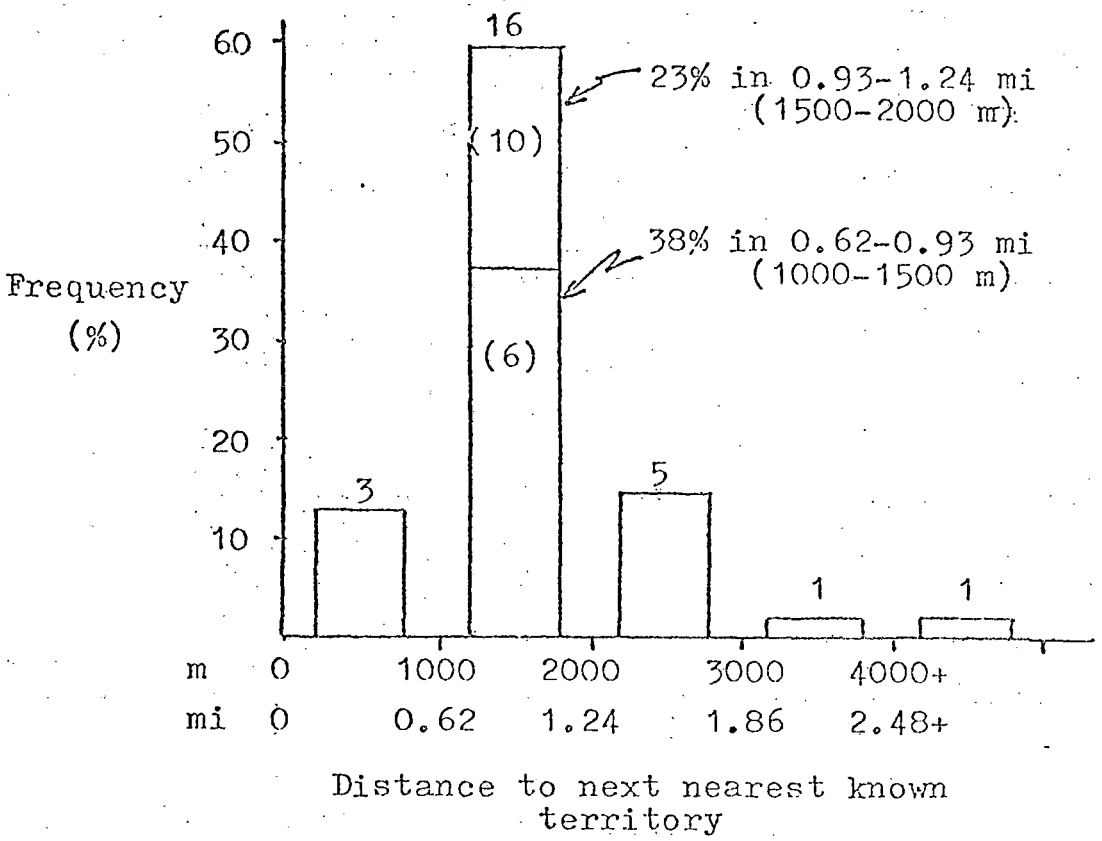


Fig. 15. Minimum distance between nearest known spotted owl territories in the timber sale study areas. Data above the bars are the sample sizes.

a wide variety of prey items. In the cedar-hemlock-douglas fir forest of Oregon, northern flying squirrel (Glaucomys sabrinus) was the principal prey species (27-48 percent of total biomass), and other important prey included bushy-tailed wood rat (Neotoma cinerea), red tree voles (Phenacomys longicaudus), snowshoe hare (Lepus americanus), Mazama pocket gophers (Thomomys mazama), small birds, western red-backed voles (Clethrionomys occidentalis), and deer mice (Peromyscus maniculatus) (Forsman 1976, Marshall 1942). However, in broad-leaved evergreen forests and areas characterized by dry-site conifers, the dusky-footed wood rat (Neotoma fuscipes) or the bushy-tailed wood rat replaced the flying squirrel as the principal prey species (27-78 percent of total biomass) (Forsman 1976).

Most of the[16] pellets taken near a Palomarin, California spotted owl nest contained dusky-footed wood rat and deer mice, and some contained band-tailed pigeon (Columba fasciata), stellar's jay (Cyanocitta stelleri), and other prey items (Beebe and Schonewald 1977). The vegetation type and prey availability of the Palomarin site is more representative of the Six Rivers NF study areas than the cedar-hemlock-douglas fir forests of Oregon; thus, it is no suprise that no remains of flying squirrel were found in the pellets. Beebe and Schonewald (1977) conjectured that the Palomarin pair hunts entirely within the wooded canyon habitat, rarely if ever venturing out into the adjacent open scrub or fields. If so, I surmise that the availability and biomass of prey in the canyon is sufficient to meet all dietary requirements of the pair; that is, the owls do not need to venture beyond the canyon to forage. The situation may be quite different with some of the Six Rivers NF study areas, as discussed below.

Spotted owls prefer to forage in the canopy and subcanopy of mature and old growth stands (Forsman 1976). However, foraging substrate, as evidenced by the sundry, particular habitats of the many prey species in the spotted owl's diet, seems more catholic. Mallette and Gould (no date) noted that spotted owls will feed on ground-dwelling prey if arboreal prey are not abundant. Such prey items as wood rat, deer mice, and voles in high relative abundances in the diet, may indicate that a fair proportion of foraging is done on the ground.

MANAGEMENT IMPLICATIONS

Critical Nesting Habitat

The northern spotted owl nests primarily within and prefers dense, old growth stands of douglas fir (D5) (Forsman 1976, 1977; Gould 1977). Nearly all territories were located from this study in old growth or mature stands of douglas fir with moderate to dense canopy cover (D4= to D4≡ and all D5). The highest absolute densities of spotted owl territories were found from this study in old growth stands bordering permanent streams.

Thus, streamside, mature or especially old growth douglas fir, which may be mixed with white fir or other conifers, seems to be optimal nesting habitat. The lack of nests or breeding territories found in other timber types indicates that this is also the critical nesting habitat. Moreover, the structural diversity of the stand seems important, as Jackman and Scott (1975:259) indicated:

> Undisturbed, mature stands are typified by varied-species composition and diversity in the stand structure (snags, umbrella crowns, mistletoe, deadfalls, natural cavities, and variety in dbh and height categories and canopy closures). The maintenance of this sort of diversity appears to be a key factor in providing acceptable habitat for spotted owls.

Multi-age composition is a necessary feature of the stand for the continuation of formation cycles of nest trees for spotted owls.

Proximity of Critical Habitat to Seral Habitat

A major consideration for the successful management of spotted owls in areas that are used for timber harvesting is the proximity of critical nesting habitat (old growth and mature douglas fir) to seral (early successional) habitat (young growth, recently-cut brushfields, natural openings, etc.). Two main aspects arise from this consideration: the amount and type of edge and area of seral habitat as affecting foraging by spotted owls, and potential predation on spotted owls by great horned owls (*Bubo virginianus*).

Foraging. That mature and old growth douglas fir is critical nesting habitat for spotted owls was discussed above. A key unknown is if the same timber type is critical foraging habitat as well.

Following radio-collared birds in a cedar-hemlock-douglas fir vegetation type in western Oregon, Forsman (pers. comm.) found that spotted owls forage almost fully in old growth douglas fir stands, rarely in clear-cuts, and virtually never in dense stands of second growth. In the Oregon study region, the northern flying squirrel, a species restricted to old growth stands for nesting, is the spotted owl's major prey item. However, in northwestern California, where wood rats comprise the bulk of the diet, are spotted owls still restricting their foraging to old growth?

Presently, the data are scant and inconclusive. In the Cape Horn study area, a spotted owl territory was found 650 ft (200 m) from a clear cut. In the Dragon study area, a pair was discovered in the top of a lone douglas fir within a clear cut, 330 ft (100 m) from the next nearest tree; the pair was already perched before calling was initiated, and they responded immediately. In the China study area, a pair was found at either edges of a clear cut which was ringed by two streams and 203 ac (82 ha) of mostly moderately dense, mature douglas fir with sugar pine (Pinus lambertiana). In the Baker Flat study area, a spotted owl was discovered 50 ft (15 m) up in the canopy of a second-growth douglas fir forest. Also, in August 1976, I heard a spotted owl calling from just within a clear cut bordering a dense old growth douglas fir-cedar stand, 3 mi (4.8 km) north of the Spike study area near Sucker Lake. More typically, however, the owls were found in mature or old growth douglas fir stands as far as 1640 ft (500 m) from the nearest clear cut, as in the Winchuck study area.

In the Jaws study area, three spotted owl territories were found along Little Jones Creek within residual old growth islands measuring just a few tens of acres each, surrounded by as much mature douglas fir stands and many acres of clear cuts. Total mature and old growth douglas fir habitat for the three territories was far less than the spotted owl foraging home ranges averaging about 2000 ac (810 ha) and ranging 900-4000 ac (364-1620 ha) that Forsman (pers. comm.) measured in cedar-hemlock-douglas fir forests in Oregon. Indeed, in the Jaws study area, the ecological density of spotted owl territories in terms of ac per territory was the second lowest in all study areas (Table 5). I conjecture from this information that the foraging home ranges of the spotted owls found along Little Jones Creek include at least some edge habitat (clear cut/mature or old growth ecotones), and quite possibly some brushfield, clear cut habitat as well. Also, rodent prey (especially wood rat and deer mice) may very well be found in greater densities along edges and in open brushfields than in the old growth stands, inviting feeding by spotted owls.

Southern and Lowe (1967) noted that in Wytham Woods, England, foraging habitats of the tawny owl (Strix aluco), the old world

equivilent of the spotted owl, were characterized by much patchiness and interspersion of plant communities, providing ideal habitat for mice and voles which comprised 70 percent of the owls' vertebrate prey. Thus, the tawny owls' hunting was importantly increased by barer ground distributed in patches in their foraging home ranges.

In summary, spotted owls may be using edge or brushfield habitat to feed, but proximity to such habitat is probably not vital for their foraging; the reaction of foraging spotted owls to seral habitat may be one of tolerance rather than either strict avoidance or attraction. The percentage of foraging in open areas may be limited by the presence of predators; thus, mature or old growth stands may be critical foraging habitat to a certain degree.

Predation by great horned owls. In the Brown study area, mimicking the call of the great horned owl caused two pairs of spotted owls to cease responding. In the Cape Horn study area, a great horned owl responded to the calling for spotted owls; the nearest spotted owl was located a mile away. In the Jaws study area, both a great horned owl and a spotted owl were heard simultaneously from the same calling station; the great horned owl was within a clear cut and the spotted owl was 330-410 ft (100-125 m) away in a dense, mature douglas fir stand. Also, in June 1977 I observed at dusk a silent great horned owl in a clear cut bordered on opposite sides by mixed conifer stands from which spotted owls were calling, in an area 4 mi (6.4 km) north of the Spike study area.

These observations indicate that great horned and spotted owls may indeed be found in the same vicinity, in contrast to several investigators' conclusions that they do not occur together (Zarn 1974). Forsman (1976) found many spotted owl territories in "close proximity" to great horned owls and evidence of at least one case of great horned owl predation on a juvenile spotted owl. In Arizona, spotted owls seem to be absent from areas inhabited by great horned owls (Phillips et al. 1964 in Kertell 1977).

Barred owls (Strix varia), eastern U.S. "counterparts" of the spotted owls, prefer large woods and require stands sufficiently mature to provide numerous nesting and roosting cavities. The lack of sufficient mature trees (basswoods) with heart rot, and presence of great horned owls in all suitable woodlots, were major factors determining the absence of barred owls in Superior Township, Michigan (Craighead and Craighead 1969). Dunstan and Sample (1972) in Michigan reported that interspecific competition between the two owls was low because great horned owls nested closer to the periphery of large

woods, whereas barred owls prefered to nest in inner regions of large expanses of mature woods, and because barred owls hatched 4 to 5 weeks later than did great horned owls. However, predation by great horned owls on barred owls may have been significant.

This information suggests that predation by great horned owls may be a significant factor limiting the distribution of spotted owls in some areas. In the Six Rivers NF where much of the mature and old growth stands of douglas fir may be interspersed by brushfields, great horned and spotted owl habitats are often in close proximity. Thus, the potential use of open, seral habitats by spotted owls for foraging, and the successful nesting of spotted owls near open areas, may be limited by the presence of great horned owls within such seral habitat. Forsman (1976) discussed other potential predators, none of which are associated so strongly with seral habitat, and thus of such major concern in a region used for timber harvesting.

Minimum Area of Critical Habitat

Minimum area of critical habitat is probably smaller in stands of mature and old growth douglas fir offering close proximity to permanent water, sufficient refuge and thermal cover, available nest sites, and abundant prey. Where any of these factors are less available, minimum area sufficient for retaining a breeding pair of spotted owls may be larger. Knowing the necessary minimum area and recognizing the special habitat requirements would facilitate timber harvest planning in areas occupied by spotted owls.

Gould (1977) found that destruction of habitat, especially from logging, was associated with spotted owls being absent at five historical locations he surveyed. On the Sequoia National Forest, he also found spotted owls in high quality habitat with as much as 30 percent of the habitat clear cut; in lower quality habitat, spotted owls were found only in areas less than 10 percent clear cut. Minimum area sufficient for retaining spotted owls thus varied as a function of habitat quality.

Ecological densities of spotted owls from this study rarely fell below 300 mature and old growth ac (121 ha) per territory and none were under 200 ac (81 ha) per territory (Table 5), perhaps indicating a critical minimum area. If spotted owl home ranges overlap, as hinted at by Figs. 11 and 12, total area necessary for the survival of greater numbers of breeding pairs in an area may be disproportionately less per breeding pair. Much remains to be learned of foraging home range sizes, the degree of overlap of home ranges, prey abun-

dance, and effects of edge and seral habitat on spotted owls in the mixed conifer forests, all of which may affect critical minimum habitat area.

Legal and Ecological Status

The spotted owl is presently considered Sensitive/Unique and an Emphasis Species (U.S. Forest Service Region 5 and Six Rivers NF listings).

The spotted owl exhibits characteristics of a "K strategist:" relatively constant habitat and population sizes, low recruitment rates, slow development, delayed reproduction, large body size, iteroparity, and a relatively long mean life span. (Pianka 1974, Emlen 1976, May 1976, Wilson 1975). Its critical habitat, mature and old growth conifer stands, is relatively constant and predictable. The spotted owl may not breed every year (Forsman 1976), or may produce variable numbers of fledged young, perhaps in response to fluctuating prey abundances, like the tawny owl in England (Southern and Lowe 1967, Southern 1970) and Germany (Wendland 1972). Population sizes of spotted owls in undisturbed areas are probably stable, despite variations in breeding success, because young eventually disperse away from the parent's territory in the fall (Gould 1977), much the same as the tawny owl (Southern 1954,1970). Dispersal is after a fairly long period (June-August inclusive) of association with the parents (Southern 1970). During this period, young tawny owls make little attempt to feed themselves (Southern 1954), indicating slow development and prolonged parental dependence, characteristics of K strategists.

In an area of accelerated and intensive timber harvesting, critical nesting habitats of the spotted owl may eventually become mature and old growth conifer islands among second growth stands. Islands of such small area may induce a more rapid local extinction rate, and if "immigration" rates of spotted owls into these islands is low, as indicated by low dispersal rates and high site (territory) tenacity, the potential for local extinction increases (Jackman and Scott 1975, MacArthur and Wilson 1967, May 1976). In other words, the distribution of critical habitat sufficient for retaining breeding pairs may not necessarily be as disjunct islands of mature and old growth conifers, but more as a distribution facilitating local immigrations and emigrations. Corridors of dense, mature stands between islands, especially as riparian highways, may suffice to maintain immigration rates.

Spotted owls, as K strategists, may be unlikely to recover from population densities significantly below their equilibrium level, and if depressed to such low levels, as by human usurpa-

tion of their habitat, especially by logging (Gould 1974,1977), they may become locally extinct (May 1976).

Thus, I recommend that spotted owls, as a species with a potentially "endangered habitat" (sensu Johnson et al. 1977), be placed on the Audubon Blue List of sensitive species.

Long-term Viability of Spotted Owl Populations

As Gould (1974,1977) indicated, a central unknown concerning the long-term viability of spotted owl populations in areas incurring habitat disturbance, is the recruitment rate. Are the spotted owl pairs found from this study successfully mating, and incubating and fledging their young? Are predation rates high enough to endanger successful reproduction? Additional studies are needed to resolve these questions. Also, unfortunately, there are no historical data on relative frequencies or densities of spotted owls in northwestern California; thus, there is no way of assessing past trends in numbers, for example, before the study areas were initially logged.

The construction and placement of nest boxes for spotted owls may encourage breeding pairs into an area deficient in nest sites (cavities in trees, old raptor nests, etc.) but otherwise suitable for breeding. Nest boxes have been successfully used with tawny owls in England (Southern 1970), great gray owls (Strix nebulosa) in Sweden (Höglund and Lansgren 1968), and ural owls (Strix uralensis) in Finland (Lahti 1972). In fact, over half the population of tawny owls in Wytham Woods, England, was induced to use nest boxes (Southern 1970). Because these species, like the spotted owl, operate as K strategists by maximally occupying suitable habitat, population densities cannot be increased by nest box placement in undisturbed areas (Southern 1970). However, nest boxes in areas devoid of natural nest sites probably would have high value.

Nest boxes for the ural owl were made of a hollowed, round log, 20-31 inches (50-80 cm) tall, 12-16 inches (30-40 cm) in diameter, with the top left open and sawed off at an angle (Lahti 1972). This design may suffice for spotted owls, but Southern's (1970) prescription may do better.

Southern (1970) discovered that tawny owls did not use nest boxes with the entrance hole in the side; tawny owls, like spotted owls, need a hollow, broken-off branch or bole with a large mouth gaping upwards as an entrance. The nest boxes were made of four 3-ft (0.9 m) lengths of one-inch (2.5 cm) plank nailed together to produce a simple, elongated box, square in section with a 7 inch (18 cm) internal measurement.

The boxes could be wired or supported with wire stays to a tree so that the open mouth pointed upward at a 45-degree angle. The bottom was made of perforated zinc for drainage and lined with coarse shavings and sawdust, and a hinged inspection door was cut in the side. A valuable accessory was a mirror attached to a metal arm screwed to the top of the box and projecting about a foot above the entrance, so that a flashlight beam could be directed from the ground below to illuminate the contents of the box (Southern 1970).

Nest boxes for spotted owls are best placed 30-100+ ft (9-30+ m) high in 1) mature, dense conifer stands deficient in natural nest sites but sufficient in thermal and refuge cover, contiguous to stands in which spotted owls are known to breed; the dispersing young may encounter and use the nest boxes and establish territories in otherwise unused stands; 2) second growth stands in similar juxtapositions; Forsman (1977) conjectured that a higher proportion of unpaired (but potentially breeding) birds may occur in second growth; and 3) in old growth islands, residual to logging, with poor or no replacement of decadent trees for natural nest sites.

Since spotted owls range quite widely, the chances of their encountering a nest box is probably much lower than for tawny owls (Forsman, pers. comm.), which occur as densely as 33 pairs per 1000 ac (400 ha) (Southern and Lowe 1967). Thus, to aid discovery by spotted owls, nest boxes may best be used in stands of suitable habitat of limited area.

The nest boxes may also require occasional cleaning, and would certainly facilitate intensive nest-watch studies.

Recommendations for Future Studies

I recommend two future studies that would provide information inportant for successful long-term management of the spotted owl on the Six Rivers NF. First, an intensive nest watch is needed, perhaps facilitated by nest boxes, to determine local breeding trends and thus the viability of the population. A comparison of breeding trends may be made between nesting pairs in heavily- vs. lightly- vs. unlogged areas, or better yet, between the same nest before and after an area is logged. Also, behavior and dispersal of the young, and predation rates could be monitored.

Second, a telemetric study would provide information on foraging activities and habitats, to help discern the impact of edges and seral stands. Ideally, both of these studies could be conducted simultaneously to derive the maximum data with the minimum cost and effort.

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APPENDIX

No. of individuals (recorded and inferred) and territories of all owl species[a] encountered during surveys. Nos. in parentheses are total nos. of individuals considered two per pair, plus others not paired.

Study area	Spotted		Flamm.		Saw-whet		Pygmy		Screech		Gt. Horned	
	Indiv	Terr	Indiv	Terr	Indiv	Terr	Indiv	Terr	Indiv	Terr	Indiv	Terr
Winchuck	5(8)	4			1(2)	1						
Baker Flat	2(3)	1			2(4)	2						
Jaws	7(13) [4(6)[b]]	6 [3[b]]			2(2)	0					2(4)	2
Butte Copter	2(4)	2										
Camp Seven	4(8)	4					1(2)	1	2[2]	1		
Sugarloaf	1(2)	1			1(2)	1						
Pen Vista	2(4)	2			1(2)	1						
Line	3(6)	3							1(1)	0		
Wilson	9(10)	4			2(4)	2						
Dragon/Creek	6(8)	4	2(4)	2								
Cape Horn	6(12)	6			1(1)	0					1(2)	1
Butte	6(8)	4										
Maple	2(4)	2			2(4)	1			1(1)	0		
China	3(6)	3							1(1)	0		
Willow	1(2)	1										
East	2(4)	2										
Spike	1(2)	1	4(7)	3								
Pilot Ridge	1(1) [1(2)[c]]	0 [1[c]]	2(2)	0								
Hastings/Skull	1(2)	1	3(6)	3								
Brown	4(6)	3										
Hetten/Shaw			1(2)	1								
Totals	68(113) 54 [68(114) 55[d]]		12(21)	9	12(21)	8	1(2)	1	5(5)	1	3(6)	3

[a]Spotted owl (Strix occidentalis), flammulated owl (Otus flammeolus), saw-whet owl (Aegolius acadicus), pygmy owl (Glaucidium gnoma), screech owl (Otus asio), great horned owl (Bubo virginianus).

[b]Three territories were outside the study area boundaries.

[c]One territory is inferred; see text.

[d]Includes one inferred territory on Pilot Ridge.